

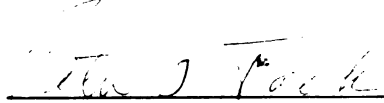
THE FRESH-WATER FISH AND FISHERIES OF
PAKISTAN WITH SPECIAL REFERENCE TO
FISH CULTURE FOR FOOD

Thesis for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY

Shamsud Doha

1964

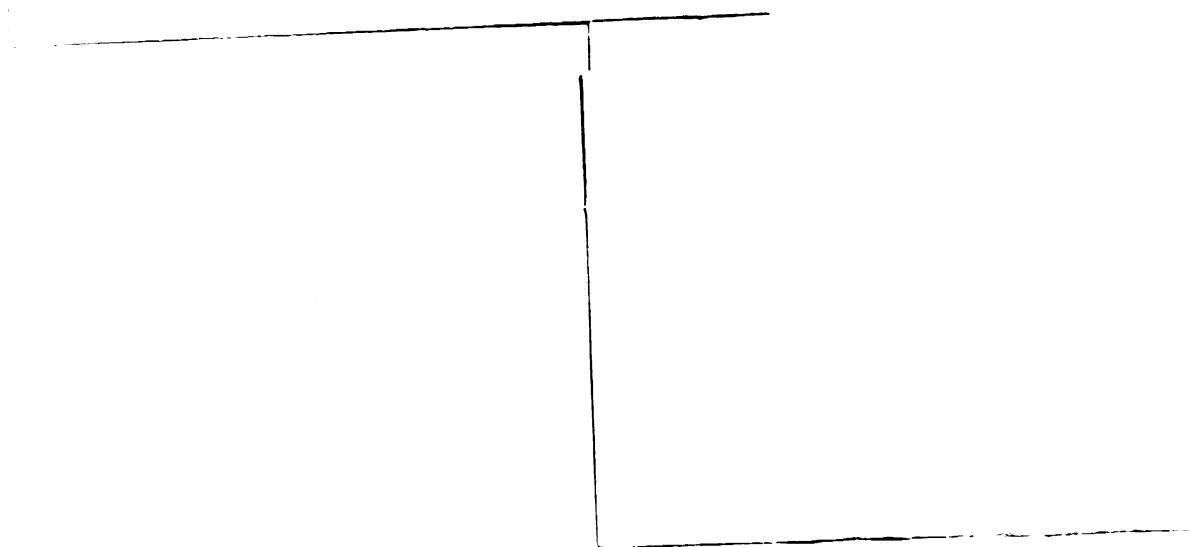
This is to certify that the
thesis entitled
The fresh-water fish and fisheries
of Pakistan with
special reference to fish culture for food
presented by
Shamsud Doha
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of the requirements for
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ABSTRACT

THE FRESH-WATER FISH AND FISHERIES OF PAKISTAN WITH SPECIAL REFERENCE TO FISH CULTURE FOR FOOD

by Shamsud Doha

The nature and present condition of the fresh-water fish and fisheries of Pakistan with special reference to fish culture for food have been investigated. The timeliness and importance of such a study cannot be exaggerated in view of the fact that fresh-water fishes supply nearly 40% of the necessary animal protein to balance the rice-vegetable diet of the Pakistanis.

The fishery resources of Pakistan have not yet been properly assessed. The fresh-water fisheries constitute nearly 70% of all fisheries of Pakistan. Over 300,000 ponds, four large and numerous small rivers and streams, lakes, swamps and rice fields support the fresh-water fisheries. The productivity of these waters are believed to be quite high, but the traditional practices of fish culture and fishing in these waters have not significantly increased the catch.

The pond cultural practices ("teichwirtschaft") in Pakistan (East Pakistan, in particular) are quite extensive.

As the indigenous carps spawn in rivers and not in culture ponds, the Pakistani fish farmer must depend on the timely supply of the stocking material. Difficulties in the transport of fish fry to the numerous stocking ponds situated far away from the spawning grounds limit, to a great extent, the maximum utilization of ponds for fish culture.

Ponds are not constructed in Pakistan on a scientific basis. A domestic pond which is excavated for the supply of necessary earth for house building is used for a variety of purposes: it supplies drinking water, it is used for bathing as well as washing, it is also stocked with fish, mainly carps--katla (Catla catla), rohu (Labeo rohita), mrigal (Cirrhina mrigala) and kalbaus (Labeo calbasu). Ponds are never limed or fertilized with standard inorganic fertilizers. Carps and other food fishes which are fattened or raised in ponds depend on the natural food supply of the ponds. Artificial feeding of carps is rarely practiced in Pakistan.

From the physico-chemical and biological points of view, Pakistan's fisheries in fresh-water rivers, lakes, swamps and rice fields are not well managed. Limnological studies of these fish-bearing waters have not yet been undertaken in Pakistan. Frequently, destructive fishing practices are employed for lack of effective conservation measures. The craft and gear are also outmoded and are not efficient in catching operation. These problems have been studied in

detail and practical measures for their solution have been suggested.

In addition to the problems of fish culture and fishing, poor means of preservation, storage, transport and marketing have further hindered a greater consumption of the fresh-water food fishes in Pakistan. Chilling and freezing of fish are not practiced in any significant amount due to the high cost involved. Curing (drying, for one) is the usual process of fish preservation in Pakistan. The public health aspects of the curing process are not adequately stressed. Transport and marketing of fish and fishery products are yet to be organized in Pakistan. The socio-economic conditions of the fishermen need great improvement. These problems also have been studied in some detail and practical measures have been suggested to solve them.

THE FRESH-WATER FISH AND FISHERIES OF PAKISTAN
WITH SPECIAL REFERENCE TO FISH CULTURE FOR FOOD

By

Shamsud Doha

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To my parents

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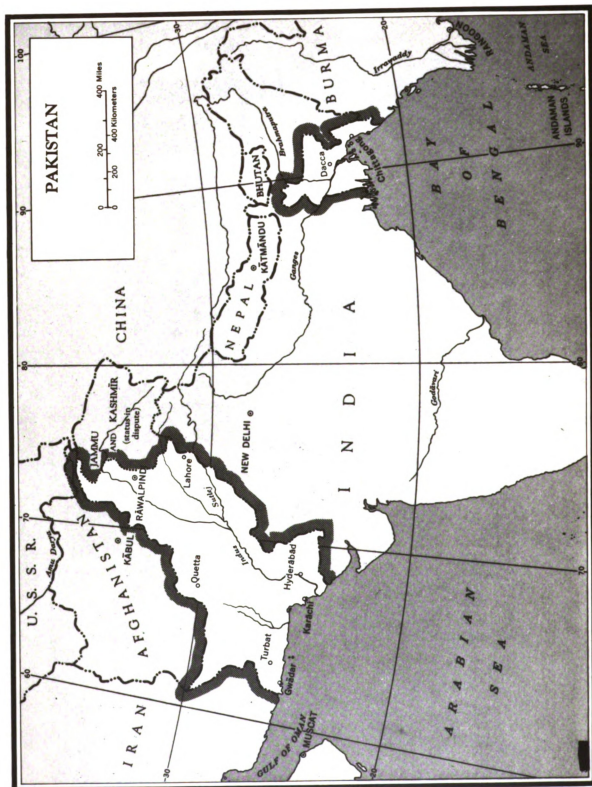


Figure 1

INTRODUCTION

Pakistan (Figure 1) with an area of 365,000 square miles and a population of 94 million has considerable fishery resources, but these have not yet been properly assessed. A 770-mile coast line, a continental shelf in the Arabian Sea and the Bay of Bengal and a large number of off-shore islands form an extensive access to marine fish, while four large and numerous small rivers, artificial lakes, reservoirs and swamps, and over 300,000 ponds form a rich potential source of inland fresh-water fish. Because of largely primitive fish cultural practices, fishing methods and inadequate facilities for preservation, storage, transport and marketing, fishery resources of Pakistan are not now being fully exploited or developed. Fishing in the seas are generally confined to a narrow belt of three miles and to the rich off-shore islands, hence the deep waters of the seas are left practically unexploited. Vast areas of inland waters remain completely or partially fallow and destructive fishing practices are often employed for lack of conservation measures.

The total protein content of the diets of the Pakistanis is low when compared with standards commonly accepted in North America and Western Europe; the animal

protein content from meat, milk and eggs is even lower (FAO, 1963). The place of fish in the Pakistanis' diet has been estimated by Borgstrom (1961a, 1962a) and is shown in Table 1.

Pakistan is more or less a flat country and all its available agricultural land are under the plough. East Pakistan occupies only 15% of the total area of Pakistan but supports 54% of its population which is increasing at the rate of 2.2% per year. The studies by Borgstrom (1961a, 1962a) have further shown how obligately the Pakistanis are depending on fish protein (Table 2).

From Tables 1 and 2 it will appear that the only practical way to improve the diet of Pakistan and to check protein malnutrition in the people is through greater use of fish. Fish is approximately 18% protein by weight and is very rich in such amino acids as lysine, methionine and tryptophan which are in poor supply in cereals (Guha, 1962). See also Borgstrom (1951) and Finn (1960).

Vegetables, rice and fish have been major foods of the Pakistanis for ages. This dependence is not likely to be changed. FAO (1962) estimated that Pakistan is 22nd among the fishing nations of the world in terms of total catch. Pakistan caught 336,600 metric tons of fish in 1962, 68% of which came from fresh-water. The production of fresh-water fish from the warm waters of Pakistan is not costly as compared with agricultural production which is now engaging 76% of its population. Production of fresh-water fish can

TABLE 1. Fish in Pakistanis' diet^a

Total population (millions)	Fish meat eaten per head per annum (kg)	Calories in daily diet	Animal protein per head per day (g)	% of fish protein in that total
94	4.5	2,130	5.7	38.6

^aSource: Borgstrom (1961a, 1962a).

TABLE 2. Pakistan's dependence on fish protein^a

Total population (millions)	% of population obtaining animal protein from fish (theoretical figure)	Additional arable land needed to replace fish %	Extra milk needed over present production %	Extra meat needed over present production %
94	39	6	35.2	137.7

^aSource: Borgstrom (1961a, 1962a).

be increased several fold if the fisheries are conducted on a scientific basis and all available fresh-water areas are improved, reclaimed or otherwise made suitable for scientific fish culture.

It is with this belief that I wish to make a critical study of the fresh-water fish and fisheries and the raising of food fish in Pakistan which will, it is hoped, create interest in, and action from, the fishery biologist as well as the administration in Pakistan.

I. THE FRESH-WATER FISH

A. The Habitat

The fresh-water fish extend from the sea level to the hill ranges in which water exists in sufficient quantities. They are found in all rivers and their tributaries, ponds, lakes, reservoirs, swamps and rice fields. Rivers and their expansions are inhabited by fishes, cultivable or otherwise, but ponds, lakes, swamps and rice fields are, and can be, used for fish culture.

1. Rivers and Their Expansions

East Pakistan has a network of rivers, the Padma, Meghna and the Brahmaputra being the three major river systems all flowing through the plains to the Bay of Bengal. The Indus, the principal stream of West Pakistan, descends from the Himalayas and flows through the plains into the Arabian Sea. Rainfall and seasonal changes affect flow, volume and the course of these rivers (Ramdas, 1946), which in turn affect the fishes inhabiting them. Table 3 shows the climatological data of Dacca, East Pakistan, and Lahore, West Pakistan.

The Indus has, besides springs, two prominent sources of replenishment. During the summer months, it receives abundant water from melted ice and snow, and a

TABLE 3. Climatological data of Dacca and Lahore, Pakistan, 1900-1960 average;
(original data supplied by the Pakistan Meteorological Office,
Karachi)

Dacca (East Pakistan)				Lahore (West Pakistan)			
Latitude--23°46'N; Longitude--90°23'E height from sea level--27 feet				Latitude--31°35'N; Longitude--74°20'E height from sea level--702 feet			
Month	Rainfall monthly mean (inches)	Temperature mean daily Max. (°F) Min.	Humidity daily mean %	Rainfall monthly mean (inches)	Temperature mean daily Max. (°F) Min.	Humidity daily mean %	
January	0.32	77.9 55.5	66.0	1.04	68.0 40.1	63.0	
February	1.24	81.7 59.0	63.0	0.97	72.1 44.5	62.0	
March	2.39	89.8 68.1	61.0	0.79	82.6 53.2	46.0	
April	5.40	92.4 74.0	65.0	0.57	94.5 63.2	34.0	
May	9.64	91.1 75.8	76.0	0.59	103.7 72.2	28.0	
June	12.39	89.2 78.1	82.0	1.64	105.9 79.0	43.0	
July	12.97	88.2 78.9	83.0	5.45	99.6 80.1	60.0	
August	13.27	87.8 78.8	83.0	5.15	97.0 78.7	62.0	
September	9.76	88.7 78.8	81.0	2.20	97.3 73.1	55.0	
October	5.27	88.2 75.3	77.0	0.24	94.0 59.8	47.0	
November	0.95	83.9 66.1	72.0	0.10	82.9 47.3	54.0	
December	0.20	78.5 57.5	73.0	0.47	72.3 40.6	66.0	
Annual total or mean	73.79	86.5 70.5	74.0	19.21	89.2 60.0	52.0	

daily rise and fall in the amount of water can be observed. Throughout the monsoon season, the rains hasten the melting of snows. Thus, with the beginning of March the Indus floods, the inundations resulting more from the melting snows than from the rains as are in the rivers of East Pakistan. The Indus forms torrents, rises and subsides rapidly especially during the rains. As this river has few contiguous oxbow lakes in which the fish can escape floods, the fish existing there must have adhesive organs, deeply forked caudal fin and very streamlined bodies which are not found so prominently in those inhabiting the East Pakistan rivers. During the cold season, the Indus, unreplenished by rains or melted snows, becomes, in places, quite small.

The rivers of the plains of East Pakistan are, of course, chiefly the continuations of those descending from the hills, but the diurnal fluctuation in the water level is scarcely apparent as they are far away from their sources, and these always have a fair supply of water.

The rivers in the hills as well as on the plains have a poor supply of water throughout the winter months. The south-west monsoon begins in June and the Indus reaches its highest levels in August, subsidence begins in September commonly being completed in November. The East Pakistan rivers overflow soon after the monsoon. During these periods of floods, the oxbow lakes receive a fresh supply of water. Thus the "dhands" (lakes) of Sind receive water from the

Indus (Figure 2).

The dhands are of two kinds: (1) isolated dhands which are in communication with the Indus only during the periods of floods and are mostly dried up before the next year's supply; and (2) connected dhands which are the expansions of a river, small stream or canal, are, throughout, or for the most part of the year, connected with running water (Day, 1873).

The Punjab with all its small rivers and irrigation canals possesses important fishing waters (Figure 2).

There is no reliable inventory of waters suitable for fish culture in Pakistan. Table 4 gives an estimate of its cultivable inland waters (Schuster, 1951; Anonymous, 1952; Hora and Pillay, 1962).

B. Taxonomy and Distribution

The important fresh-water food fishes belong to the order Physostomi and especially the families Cyprinidae, Siluridae, Ophicephalidae and Clupeidae. Some are also found in the order Acanthopterygii (Weber and de Beaufort, 1911-1936; de Beaufort, 1940; Day, 1958). Other orders of fresh-water fishes are used as food by the poorest inhabitants only, or are entirely rejected. A comprehensive list of the fresh-water food fishes of Pakistan is given in the Appendix which will give an idea of Pakistan's piscine wealth. Most of the important food fishes are common to both parts of Pakistan with the exception of a catfish (Clarias batrachus) from West

Figure 2. West Pakistan inland fisheries map, 1962



Figure 2

TABLE 4. Estimated area of cultivable inland waters of Pakistan^a

Category	Area (hectares) ^b
Fish ponds	
Fresh-water	105,000
Brackish-water	24,000
Natural lakes	30,100
Artificial lakes, reservoirs, channels, etc.	68,500
Salt or mangrove marshes	
suitable for fish culture	305,200
Lagoons and estuarine waters	
suitable for fish culture	424,000
Rice fields	
Without fish culture	43,400
With fish culture	12,000
Total inland waters	1,012,800
Arable land	21,000,000
Total area of country	94,300,000
% of cultivable inland waters	
to total area of country	1.2

^aSources: Hora and Pillay (1962); Schuster (1951); Anonymous (1952).

^bOne hectare = 2.2 acres.

Pakistan (Ahmad, 1953). The important food fishes of the two provinces (East Pakistan and West Pakistan) include the carps (Catla, rohu, mrigal and kalbaus), the catfishes (Saccobranthus fossilis, Wallago attu, Mystus aor and Silonia silondia), the snakeheads (Ophicephalus spp.), and the featherbacks (Notopterus spp.).

Among the most important estuarine food fishes that frequent the fresh-waters of Pakistan are the hilsa or shad (Hilsa ilisha), perch (Lates calcarifer) and the mullets (Mugil spp.).

Fishes that inhabit the fresh-waters of Pakistan are either migratory or non-migratory. Some of the migratory species such as mahsir (Barbus tor) of West Pakistan ascend the hill streams from the rivers of the plains for breeding purposes whereas others which never leave the plains may sometimes be estuarine such as Hilsa ilisha. Others are entirely fresh-water species such as carps. Migrations in adult fish are effected for breeding, predation or to obtain food. Among the non-migratory fishes are the loaches and small catfishes of the hill streams and the ambassids such as Ambassis baculis of the plains. The majority of the breeding fishes are polygamous but some are monogamous such as the snakeheads. The breeding time varies with seasons and localities. The migratory ones almost invariably select the monsoon time (June to September).

The carps belong to the family Cyprinidae. They have no teeth in their jaws but carry them on their inferior pharyngeal bones. None of them has more than one dorsal fin. They are grouped in three sub-families (Day, 1873):

1) Cobitidinae or the little roaches extend throughout Pakistan's fresh-waters, from sea level to many thousand feet elevation, even breeding in places where the rivers are almost entirely replenished by melting snows. Loaches such as Nemacheilus sp. are excellent food for the larger fishes and are also esteemed by the people. Their air-vessel is more or less enclosed by bone.

2) Homalopterinae or sand grubbers have no air-vessel, are insignificant in number and size, and reside under stones in streams along the bases of hills or at moderate elevations.

3) Cyprininae or true carps are widely distributed and are the most important food fishes. Their air-vessel is not covered by bone. These carps are divisible into those of the hills and those of the plains. The hill carps again can be subdivided into those which permanently reside there and those which are occasional or periodical visitants that ascend for breeding or a change in their food. The non-migratory hill carps like Oreinus sinuatus are an important article of food there for the resident population. The migratory hill carps are those which breed in small streams of the hills but descend to the rivers of the plains where

they reside during the cold and dry months of the year when the small hill streams would be unsuited for their residence because they either dry up at this time or do not support sufficient food. They reascend to the base of the hills during the summer months and with the first burst of the monsoon return to the hill region (example, Barbus tor).

Among the carps of the plains are a very large and varied number of species some of which are migratory while others are not. These migrations are mostly effected for breeding purposes and generally take place during the southwest monsoon. The finest carps belong to the genera Labeo, Cirrhina and Catla which will be referred to as the major carps.

The fishes belonging to the family Siluridae are commonly known as catfishes. They have a number of barbels arranged around their mouth. They prefer muddy to clear water. The more developed and numerous these barbels are, the better they are adapted for an inland and muddy freshwater habitat. Catfishes are scaleless and are generally armed with serrated spines in the dorsal and pectoral fins with which they may inflict severe wounds. The large muddy rivers of East Pakistan are very well-suited for the catfishes (Hora, 1934).

The fresh-water catfishes may be divided into those of the hills and those of the plains; the former being small in size and often possessing a thoracic adhesive apparatus to

enable them to adhere to rocks and thus prevent their being carried away by the descending torrents. The catfishes of the plains are very numerous, existing in almost every piece of fresh-water while the larger rivers contain some such as Pangasius pangasius, Wallago attu, and Bagarius bagarius. None of these possesses any adhesive apparatus.

The snakeheads belong to the family Ophicephalidae. They are considered excellent food in the Punjab, West Pakistan (Khan, 1934).

The herring family Clupeidae furnishes examples of both migratory and non-migratory species in the fresh-waters. Among the migratory herrings, the best known is the hilsa (Hilsa ilisha). It ascends the fresh-water rivers for breeding during the monsoon. The non-migratory herrings such as Gadusia chapra live and breed in ponds and lakes.

The percomorph fishes are not found in any great numbers in the inland fresh-waters. They are more abundant in the coastal districts than far inland. Among the perches are Anabas testudineus, Colisa fasciata, Nandus nandus, Lates calcarifer, Mugil spp. and some others.

C. Respiration of Fresh-water Fishes

Fish generally breath through gills. A number of food fishes such as the catfishes (Clarias batrachus and Saccobranhus fossilis), the climbing perch (Anabas testudineus), and the snakeheads (Ophicephalus spp.), live

in pools and marshes. They have developed remarkable air-breathing systems. Lack of oxygen in the shallow tropical waters must have been responsible for the evolution of such an air-breathing habit. Their complicated accessory respiratory organs point to the same conclusion. It is a well-known fact that in the animal kingdom the area of respiratory epithelium is increased in waters deficient in oxygen. In the dry season the water of pools and marshes becomes stagnant, and, as a result of putrefaction, the oxygen is gradually reduced till, in some cases, the water becomes almost totally devoid of oxygen. In these circumstances, the fish, if they are to survive, must develop increased respiratory surfaces (Das, 1928). These may develop as outgrowths either of the pharyngs or the opercular cavity as in Clarias batrachus (PLATE V). Table 5 shows the air-breathing organs of some fishes of Pakistan and the method of their blood circulation (Carter, 1957). See further Fry (1957).

The young of Anabas, Clarias and Saccobranchus living in clean water are pure water-breathers. Their air-breathing habit is developed only when the growing fish begin excursions out of the water in pursuit of prey or in search of new ponds. The air-bladder of Clarias and Saccobranchus is very much reduced and degenerate in the adult stage. Snakeheads (Ophicephalus spp.) can breed in foul water and the young gulp air from the beginning. Experiments (Das, 1928) have shown that the snakeheads die if deprived of

TABLE 5. Air-breathing fishes and their blood circulation^a

Name of fish	Air-breathing organ	Blood circulation	
		Afferent	Efferent
<u>Ophicephalus</u>	Pharyngeal epithelia	Aortic arches	Jugular vein
<u>Clarias</u>	Epithelia of branchial chamber	Afferent arches	Efferent arches
<u>Saccobranthus</u>	Epithelia of branchial chamber	Afferent arches	Efferent arches
<u>Anabas</u>	Epithelia of branchial chamber	Efferent arches	Jugular vein

^aSource: Carter (1957).

access to the air even when they are kept in water saturated with oxygen.

According to Hora (1935), the habit of air-breathing has developed along two distinct lines: (1) by an increase of respiratory surface for aquatic respiration and direct contact with the air afterwards, and (2) by surfacing to get the better oxygenated water and then taking in occasional gulps of air and passing it over to the gills. In either case, the stimulus is supplied by the lack of oxygen in the water.

II. THE FRESH-WATER FISHERIES

The fresh-water fisheries of Pakistan may be classified under the following categories: (1) carps, (2) catfishes, (3) live fishes (snakeheads and perch), (4) featherbacks (Notopterus spp.), and (5) eels. Carps account for nearly 40% of the total fresh-water catch being closely followed by catfishes.

Among the anadromous fisheries, the hilsa (Hilsa ilisha) (PLATE VI) provides the most important single fishery of particularly East Pakistan.

A. Production

The magnitude of fresh-water fisheries can be ascertained from the catch and landing statistics. Collection of fishery statistics is still in its infancy in Pakistan. Table 6 gives an estimate of Pakistan's catch of fresh-water fishes which come mostly from East Pakistan.

Catch statistics of hilsa are available in Pakistan since the beginning of the hilsa investigation project in 1955 (Table 7).

Hilsa is available in East Pakistan throughout most of the year. Except for the Rivers Brahmaputra and Tista which have rapid currents, hilsa ascends several hundred miles inland (Ahmad, 1954). There are two runs, one in

TABLE 6. Catch of fresh-water fish in Pakistan^a

Year	Total catch	Fresh-water catch	% Fresh-water
. 1,000 metric tons			
1948	na	8.5	----
1955	270.9	169.0	62.4
1956	277.0	168.9	61.0
1957	282.8	191.2	67.6
1958	283.7	192.3	67.8
1959	290.1	196.3	67.7
1960	304.5	195.0	64.0
1961	319.1	216.6	67.9
1962	330.6	na	----

^aSource: FAQ (1962); na = not available.

TABLE 7. Catch of hilsa in Pakistan^a

Province	1955	1958	1959	1960
	 1,000 metric tons			
East Pakistan	20.0	20.0	20.0	15.0
West Pakistan	2.0	3.0	1.0	0.9
Total	22.0	23.0	21.0	15.9

^aSource: Anonymous (1961).

winter and the other during the monsoon, the latter providing the bulk of the total catch.

In West Pakistan, only the River Indus supports a hilsa run (Qureshi, 1954). The run starts from the middle of February and ends in mid-October; the peak season being reached from May to July. There are about 150 miles of hilsa fishing area of Sind (see Figure 2).

Preliminary investigation conducted on the population of hilsa shows that there is only one species in the Indus and that there are probably two races in the rivers of East Pakistan (Pillay, 1952; Anonymous, 1961).

The information on the migration of hilsa is largely based on the observations of fishermen's catches. Day (1873) concluded that hilsa were anadromous in the Gangetic rivers and stated that the fish spends a part of its life in the sea, not far from the shallow coastal belt. Prasad (1919) doubted whether it is truly anadromous as it is found in the rivers throughout most of the year. Hora (1938) observed that it rarely goes into the sea and supported Prasad's (1919) contention that it is not a truly anadromous species. Naidu (1939), however, maintains a reverse opinion.

Hora and Nair (1940) studied the young hilsa (Jatka) of East Pakistan and stated that they are two to five months old when they migrate from estuaries into fresh-water for feeding. Naidu (1939) and Pillay (1955) believe that Jatka

hilsa belong to a distinct stock and their ascent of the rivers in January and February is for spawning. Spawning takes place in the tidal waters and in the middle reaches of large rivers. Floods and sexual maturity induce the fish to undertake the upward migration (Hora, 1941).

The extent of migration of hilsa differs greatly in various river systems of Pakistan. In East Pakistan, they migrate several hundred miles up from the mouth of the rivers. Hilsa was not available in the upper reaches of the Rivers Padma and Jamuna (specially in the northern region) probably due to silting and construction of a dam. East Pakistan rivers carry about one billion metric tons of silt every year. Prior to the construction of the Ghulam Muhammad (G.M.) Dam over the Indus in 1955, hilsa ascended to the Sukkur Dam (see Figure 2), 100 miles farther up on the same river, but now it is restricted by the G.M. Dam only, a distance of 150 miles from the mouth of the river. The decline in the catch of hilsa (70%) in the River Indus from 1958 to 1960 (Table 7) is believed to have resulted from the construction of the dam. Day (1873) considered it essential to provide fish passes to facilitate the migration of hilsa to the upper reaches of rivers in which artificial obstructions have been constructed. Observations made on fish passes provided in the G.M. Dam indicate that hilsa does not negotiate them (Anonymous, 1961). It appears desirable that detailed studies like the researches on anadromous fish

passes at dams by Collins (1954) and Collins and Elling (1960) in the United States be carried out to determine how seriously they threaten the existence of the hilsa fishery because many more dams will result in future from the development of water resources for power, irrigation, navigation and flood control, and to determine ways to help it going up the dams for breeding. For a comprehensive treatise on fishways and other fish facilities see Clay (1961).

In respect to fresh-water fish production, Pakistan is fifth among the world's fresh-water fish producing nations, as shown in Table 8.

B. Fishing Craft and Gear

1. Craft

The total population of fishermen in Pakistan has been estimated at 662,500, 98% from East Pakistan (Anonymous, 1961). In 1960, they conducted fishing from a total of 30,799 fishing boats, 85% of which were used in inland fisheries. More than 50% of these are sail and row boats with a capacity of less than one ton. As of 1960, none of the boats used in inland fishing was mechanized. Table 9 shows the number of Pakistani fishing craft used in fresh-water fisheries and their value in 1,000 Pakistani rupees.

TABLE 8. Freshwater fish production in principal countries, 1958-1960^a
(1,000 metric tons)

Country	1958			1959			1960			% of world total 1959-60
	Total	Fresh-water	% Fresh-water	Total	Fresh-water	% Fresh-water	Total	Fresh-water	% Fresh-water	
World	32,100.1	3,810.0	11.9	35,330.0	4,300.0	12.2	37,730.0	4,370.0	11.6	100
China	4,060.0	1,560.0	38.4	5,020.0	2,020.0	40.2	5,500.0	2,320.0	40.0	47.0
USSR	2,620.0	460.2	17.6	2,760.0	465.4	16.9	3,051.0	431.6	14.2	10.3
Indonesia	685.0	264.0	38.5	700.0	300.0	42.8	na	na	na	7.0
India	1,064.4	308.7	29.0	822.8	238.6	29.0	1,159.9	281.7	24.3	6.0
PAKISTAN	283.7	192.3	67.8	290.1	196.3	67.7	304.5	195.0	64.0	4.5
Cambodia	160.0	142.2	89.0	na	na	na	na	na	na	3.7
Congo	136.6	131.6	96.3	154.4	147.5	96.3	na	na	na	3.4
Thailand	196.3	48.0	24.4	204.7	57.0	27.8	220.9	70.9	32.1	1.5
U.S.	2,703.6	65.4	3.4	2,889.7	65.8	2.3	2,796.9	64.4	2.3	1.4

^aSource: Borgstrom (1962b); na = not available.

TABLE 9. Fresh-water fishing craft of Pakistan since 1953^a

N = number of craft
V = value in 1,000 Pakistani Rupees^b

Category, capacity		1953	1956	1957	1958	1959	1960
Total (including	N	29,005	29,758	29,875	29,911	30,147	30,779
marine fisheries	V	23,486	28,243	28,392	29,100	39,914	52,055
Inland fisheries	N	25,470	26,000	26,015	26,025	26,035	26,035
	V	17,291	17,790	17,806	17,813	17,820	17,820
Sail and row boats:							
Under 1 ton	N	15,970	16,220	16,225	16,230	16,235	16,235
1-2 tons	N	6,500	6,635	6,640	6,645	6,650	6,650
Over 2 tons	N	3,000	3,145	3,150	3,150	3,150	3,150

^aSource: F.A.O. (1961).

^bOne rupee = U.S. \$0.21.

2. Gear

One of the main reasons for the inadequate exploitation of the fish stocks in Pakistan is the low technical standard of the gear used. This condition is manifest particularly in inland fisheries. The present techniques and organization of the inland fisheries in rivers, lakes, reservoirs and ponds is characterized by a great diversity of fishing gear. As fishes occupy a wide range of habitats, the method of their capture differs. They are either netted, trapped, speared or taken by hook and line.

Nets

These, broadly speaking, can be divided into nine categories. Each category varies in details from place to place even within the same district. Also the same type of net bears different names and sometimes there are numerous names for one and the same net in different districts (Table 10).

The choice of nets depends on the area of operation: for example, most of the ponds can be dragged. Seines are used in rivers, but during the monsoon, these nets cannot be used because of rapid currents and gill nets are used instead. This is especially so for hilsa (Jones, 1959; Ahmad, 1961).

Traps

In addition to nets, 26 types of bamboo traps are used in shallow waters where nets cannot be operated.

TABLE 10. Types of fishing gear of East Pakistan^a

Type of nets	Number of varieties	*Size of mesh (inch)	Type of fish caught
Gill nets	30	0.50-10.0	Hilsa, carps and catfishes
Seines	30	0.25- 6.0	Snakeheads, carps, hilsa and catfishes
Drag nets	11	0.06- 3.5	All types
Trawls	6	0.12- 1.0	Bottom types
Clap nets	6	0.12- 4.0	All types
Fixed purse nets	5	0.50- 4.0	Small fish of all types and shrimp
Stake nets	9	0.25- 4.0	Carps and catfishes
Dip nets	16	0.50- 1.0	All types of small fish
Cast nets	3	0.25- 3.0	Carps, catfishes and snakeheads

*One inch = 25.40 mm.

^aSource: Ahmad (1961).

Spears and Harpoons

These are also widely used throughout East Pakistan. Big carps and snakeheads are the common targets. For a detailed review of the fishing gear of East Pakistan see Ahmad (1961).

Gear Improvement

The construction of the gear presently used is poor as compared to modern standards and their efficiency is therefore low. A radical change of the gear and methods or the introduction of techniques used in progressive fisheries elsewhere is required to increase the technical level and increase production.

The large variety of fishing gear used at present in the inland fishery obstructs, to a considerable extent, proper management and the use of optimum commercial fishery practices. The fishermen construct their nets according to local customs regardless of the specific fishing conditions and the distribution and behavior of fishes, so that the structure of the gear does not take into account the species it is intended to catch nor the peculiarities of the area.

Among the large variety of the gear, gill nets constitute about 80% of the total. The construction of these nets is technically inefficient, the main shortcomings being:

- 1) Incorrect selection of twine for the webbing of different mesh size.

- 2) Deformed shape of the webbing and a reduction in area of catch.
- 3) Irregular distribution of floats along the float line causing sag of the nets.
- 4) Erroneous method of net hanging which restricts the operation.

To improve the fishing techniques in fresh-waters

(1) immediate alteration in construction of gill nets now in use is advisable. The most important alterations to be made are:

- a) Complete framing of the nets attaching breast lines, a float line and a lead line.
- b) Uniform distribution of the buoyancy along the float line and similarly equal distribution of sinkers along the lead line.
- c) Application of a hanging coefficient of 0.5 when rigging the nets (e.g., 450 feet stretched webbing hung to 225 feet of rope).

(2) Gradual introduction of more efficient fishing gear of the following types:

- a) Drifting gill nets of synthetic twines having mesh sizes of 2, 2.5, 3, 3.5, 4, 4.5 and 5 inch-bar to catch Silonia silondia, Pangasius pangasius, Cirrhina mrigala, Barbus spp, and Hilsa ilisha.

- b) Bottom-set gill nets of synthetic twine having mesh sizes of 2 and 2.5 inch-bar to catch Cirrhhina reba, Hilsa ilisha, Mystus aor, Barbus sarana, Wallago attu and Labeo calbasu. See Figures 3 and 4 for the general construction drawing of these two new types of nets.

(3) For the purpose of unification and for optimum exploitation of the fish stocks, a thorough analysis of the local fishing gear should be carried out with a view to restricting the number of gear types to those with efficient commercial qualities. This action will allow better use of net materials, facilitate the technique of manufacturing and distribution of fishing gear and lead to the setting up of centralized production of more efficient nets.

(4) Withdraw from circulation the small-meshed (below 2 inch-bar) fishing gear which, apart from being commercially rather inefficient, cause damage to the fish resources, by catching fish below optimum size.

(5) Work out a better procedure to supply the local Fisheries Offices and Stations with net materials of improved qualities in adequate assortment and in sufficient quantities. This would make it possible for many fishermen to undertake very quickly full reconstruction of the gear and tackle now in use. It would also speed up the introduction of new gear.

Figure 3. General construction drawing of a drifting gill net. The webbing is made of synthetic twine or monofilament of appropriate strength. Mesh size: 2, 2.5, 3, 3.5, 4, 4.5, and 5 inch-bar. Main species to be caught: Hilsa ilisha, Silonia silondia, Pangasius pangasius, Cirrhina mrigala and Barbus spp. Source: Gulbadamov (1961).

Figure 4. General construction drawing of a bottom-set gill net. The webbing is made of synthetic twine or monofilament of appropriate strength. Mesh size: 2 and 2.5 inch-bar. Main species to be caught: Hilsa ilisha, Cirrhina reba, Mystus aor, Barbus sarana, Wallago attu and Labeo calbasu. Source: Gulbadamov (1961).

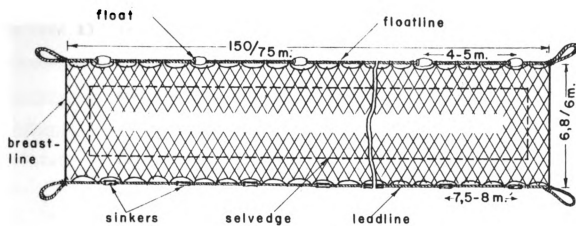


Figure 3

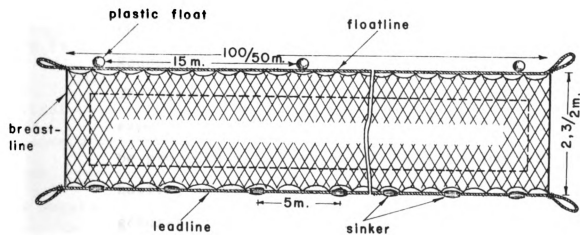


Figure 4

Other measures to improve fishing techniques in inland waters of Pakistan, over a long term, are:

- 1) Training the personnel in fishing technology and teaching the local fishermen how to make, rig and operate different kinds of gear in an efficient way. Training courses may be organized from time to time. Publication of handbooks giving instruction on fishing techniques is also suggested.
- 2) Survey of the important inland water bodies regarding the bottom configuration, distribution of fish according to seasons, finding the most productive area and the general characteristics of the water body should also be carried out (Hubbs and Eschmeyer, 1938; Welch, 1948; Rounsefell and Everhart, 1953; Lagler, 1956). The survey team should consist of skilled and experienced fishermen and fishery officers and be provided with mechanized boats equipped with hauling in gear, echo sounder, fishing lamps, generator and electro-fishing appliances.
- 3) Along with the adoption of new progressive gear and methods, measures must be taken to secure reproduction and conservation of the stock of commercially valuable species (Gulbadamov, 1961).

Gear Preservation

Excluding some nylon nets imported from Japan, gear is made of sunn hemp (Crotalaria juncea) and cotton. The common gear preservatives are the fruit juice of "gab" (Diospyros embryopteris), bark of "goran" (Ceriops roxburghiana) and coal tar. Research on gear and its preservation is needed in Pakistan.

C. Preservation

Increase in fish production will, of course, be of limited value unless efficient methods of preservation are adopted at the same time so that supplies can be made available to the consumers living far from fishing centers. Unsatisfactory methods of handling and preservation decrease greater consumption of fish even in the major fishing centers (van Veen, 1953; Doha, 1963).

Preservation is basically an interruption of the natural changes that occur in dead tissues. Preservation becomes necessary when the entire catch cannot be consumed fresh. During the seasonal glut, the only way to utilize the surplus crop is to process it for storage.

Spoilage

The present knowledge of the spoilage processes in fresh-water fish is scanty compared with that of sea-fish. There are, however, many similarities between the spoilage patterns of these two categories of fish.

Since the change is gradual from a fresh condition to staleness and then to inedibility, it is rather difficult to determine the first appearance of spoilage. With the beginning of spoilage, the bright characteristic colors of the fish fade, and then dirty yellow or brown discoloration appears (Tanikawa and Doha, 1964). The slime on the skin of fish increases, especially at the opercula and gills. The eyes gradually sink and shrink, the pupil becoming cloudy and the cornea opaque. The gills turn into light pink finally becoming grayish yellow. Most marked is the softening of the flesh so that it exudes juice when pressed and becomes easily indented by the fingers. The flesh is easily stripped from the vertebral column where a reddish-brown discoloration develops toward the tail which is a result of the oxidation of hemoglobin. A sequence of odors due to hydrogen sulfide, ammonia, indole, etc., will result from the spoilage of fish. Cooking will bring out the odors more strongly (Reay and Shewan, 1949; Tressler and Lemon, 1951). See further Farber (1964), and Tomiyasu and Zenitani (1957).

In recent years, it has been shown that not only microorganisms (bacteria, yeast, etc.) and their metabolic products are responsible for the deterioration of fish meat, but that the enzymes of the fish muscle and the intestines are also involved in the spoilage. The muscle enzymes are particularly active in the initial phases. In storing whole

fish, as is commonly done with fresh-water fish, intestinal enzymes may invade the muscle tissue, thus causing spoilage. Most essential, however, is the finding that the bacterial enzymes may exert a certain influence. But not only bacteria are responsible for the spoilage of fresh-water fish; intrinsic enzymes may also participate. The presence of certain fish muscle enzymes appears to be a prerequisite for an optimal growth of bacteria which cause spoilage (Bramstedt and Auerbach, 1961). See further Reay and Shewan (1949); Frazier (1958); Siebert (1958).

Rigor Mortis

Rigor mortis is an important factor in fish spoilage. The onset and duration of this phenomenon depend upon a number of factors such as the glycogen-ATP relationships. The pH, reaching acidic values after death, enhances the hydrolyzing activity of some enzymes and the splitting of proteins. Besides glycogen, a number of carbohydrate breakdown products like D-ribose, glucose and hexose phosphates, are encountered in fish muscles (Tarr, 1954a).

Tarr (1954a) compared the occurrence and duration of rigor mortis in marine and fresh-water fish (mackerel, red snapper and carp). The rate of glycolysis decreased in the order: mackerel, red snapper and carp. The changes in the ATP content and free SH-groups showed very slight differences among them. Fish killed just after agony had a lower content

of glycogen, ATP, and free SH-groups and a lower pH than the controlled groups.

Amlacher (1961) has discussed the intricate relationship of rigor mortis in fish. With regard to freshwater fish like common carp, it has been found that ATP disappears parallel to rigor mortis and it completely vanishes within six hours. ATPase causes the breakdown of ATP and, as in the case with mammals, ATPase is tied with the myosin fraction. The amount of free SH-groups in carp muscle diminishes continuously right from the time of death, but in 15-20 hours, the trend is reversed due to the process of putrefaction (Partmann, 1952-53).

The quality of fresh market fish depends upon the duration of rigor mortis and the time for its onset. The present knowledge of the biochemistry of rigor mortis is still scanty and much further research is required.

The Role of Microorganisms

Fish muscles are generally considered sterile as such in nature. However, the microorganisms active in the spoilage of fish originate largely from contamination subsequent to capture. They may not belong to typical water bacteria, but rather be classified as air, soil, plant or waste bacteria. See further Bramstedt and Auerbach (1961). These microorganisms enter the gills and the vascular system and thus invade the body. The greater the load of

microbes, the more rapid will be the spoilage. Non-eviscerated fish do not have their flesh contaminated with intestinal organisms but they may become odorous because of decay of food in the gut and diffusion of decomposition products into the flesh. This process is hastened by the digestive enzymes attacking and perforating the gut wall, the abdominal wall and viscera. Evisceration spreads intestinal and surface slime bacteria over the flesh but thorough washing will remove most of the organisms and adequate chilling will inhibit growth of those left. Any damage to skin or mucus membrane will harm the keeping quality of the product (Hess, 1950; Tarr, 1954b; 1962).

Oil Oxidation

The present knowledge of the biochemical processes of fat breakdown in fresh-water fish is very scanty. Most investigations refer to marine species. This is partly explained by the fact that fresh-water fish are not held to the same extent as sea-water fish or any length of time. Mostly they are consumed shortly after capture. Hilsa, an oily fish, deteriorates rapidly probably because of oxidation of its unsaturated fats. Carps do not spoil as rapidly as hilsa.

Bramstedt and Auerbach (1961) conclude that the initial steps of spoilage in the widest sense of the word are not entirely undesirable. The optimal taste and the

best quality will be reached only if the biochemical processes connected with rigor mortis are resolved. Any preservation prior to rigor mortis does not give satisfactory results. The initial steps of spoilage are characterized by the appearance of substances partly essential to an optimal taste.

Chilling

Chilling is a commonly used method in the advanced countries (e.g., United States) for delaying or preventing microbial growth and spoilage until the fish is used or otherwise processed. It is seldom practiced in Pakistan due largely to inadequate production and, consequent high price of ice. Fish stored in ice made with a solution of 0.1% NaNO_2 and 1% NaCl kept in good condition for 94 hours. The two chemicals act synergistically in lowering the rate of spoilage in fresh-water fish (Bose and Dutt, 1954). The chlortetracycline (CTC) ice was found to have no effect in prolonging the keeping quality of round and eviscerated fresh-water fish when stored at 30°C (Visweswariah et al., 1959). However, the effectiveness of CTC in prolonging the storage life of fish fillets stored under identical conditions is demonstrated (Tarr, 1961). See further Iyengar et al., 1959).

Processes of Preservation

Traditional Methods

1. Sun-drying.--This is the usual method of fish preservation in Pakistan since the days of the Indus Civilization (Cutting, 1955). Small fish (less than three inches long) are dried whole, while those larger than that are eviscerated, scaled, washed and dried in the sun.

Sun-drying is a slow process. The microorganisms cause a considerable breakdown of the product including the development of off-flavors before their activity is arrested. The fish shrinks during the drying process and the product becomes tough. In addition, the denaturation of protein occurs (Doha, 1963).

2. Salting.--Hilsa is salted commercially in East Pakistan after proper evisceration and cleaning. Salt extracts water from the fish flesh by exosmosis and also penetrates the flesh thereby inhibiting the activities of many types of bacteria, although some species are able to survive even in saturated salt solutions. Colonies of halophilic bacteria are often characteristically pink colored.

Sea salts are almost always used in salting fish. Pure sodium chloride should be used in salting because calcium and magnesium salts and all sulfates present in the sea salts as impurities retard the rate of penetration of sodium chloride, indirectly permitting more rapid breakdown of the

fish muscle protein. In addition, these impurities stiffen the product (Tressler and Lemon, 1951; van Klaveren and Legendre, 1964; Voskresensky, 1964).

3. Smoking.--Smoking of fish is perhaps as old as the discovery of fire. The production of smoked fish involves four interrelated processes: (a) salting, (b) drying, (c) heat treatment, and (d) smoking (Shewan, 1945). Smoking imparts to the fish a smoked flavor and color. Phenols usually found in wood smoke are deposited on the fish and produce the characteristic color (Linton and French, 1945). The preservative action of the deposited constituents of the smoke is only slight, although phenols, aldehydes, and possibly fatty acids in the concentrations deposited on the fish may serve as mild antiseptics. Despite the beneficial effects of brining, drying and smoking, smoked fishery products are highly perishable. See also Cutting (1964).

4. Icing.--It is a process which is adopted during transport of fish from the fishing grounds to the consuming centers. Icing as a means of preserving wet fish is a short term process usually for a very few days. Ice and cold storage facilities are far from being adequate in Pakistan. There are no special facilities for cold storage of fish. Whatever space is available is in the form of mixed stores for all types of perishable goods such as potato seeds, vegetables, fresh fruits, etc. Also there are no cold storage or ice plants located near the fishing grounds,

landing jetties or wholesale fish markets. Ice has to be purchased from depots at least two to three miles away. There are altogether 177 ice factories in Pakistan capable of producing jointly a maximum of 1,524 tons of ice per day. Cold stores are attached to only 14 ice factories. These have a total storage capacity of 3,435 tons, as shown in Table 11 (Jaleel, 1955).

Modern Methods

1. Freezing.--There are few industries which depend more fully on refrigeration than the fish industry. It is mainly to arrest or retard autolysis and microbial invasion and putrefaction that low temperatures are employed. If more than a few days' storage is necessary, the fish must be frozen hard and kept in that condition for the entire period of storage. Freezing and storage, if done by the best known methods, make possible the holding of fish in good edible condition for a year or more for many species (Plank, et al., 1916).

In the freezing, storing and thawing of fish intended to prevent autolysis and putrefaction, certain other undesirable changes may supervene which must be clearly recognized and avoided as far as possible. These include:

a. Physical changes.--The physical changes which occur during freezing and storage of frozen fish comprize internal crystallization of water with the expansion of the

TABLE 11. Ice production and cold storage facilities in Pakistan^a

Province	Number of existing ice factories	Number of ice factories to which cold storage are attached	Maximum ice production per day (tons)	Maximum storage capacity (tons)
East Pakistan	24	none	154	none
West Pakistan	153	14	1,370	3,435
Total	177	14	1,524	3,435

^aSource: Jaleel (1955).

volume and desiccation starting from the surface of the frozen fish. Slow freezing results in the formation of large ice crystals resulting in the rupture of cell walls, rapid autolysis, and drip during thawing. On the other hand, rapid freezing results in the formation of small ice crystals and the quality of a quick frozen fish may be nearly equivalent to that of fresh, unfrozen fish (Heen and Borgstrom, 1964).

b. Desiccation.--Loss of water from the surface of the frozen fish during freezing and storage will be rapid if the temperature difference between the fish and the evaporator and the velocity of the circulating air increases. The fish, unless carefully protected, may lose as much as 55% of the weight in a few months. As the fish dries, the skin shrinks and loses its luster, the tissues become rubbery and the fish is unacceptable as food.

c. Biochemical aspects.--The rate of glycolysis increases during freezing and storage and that storage in the frozen state generally reduces the activity of one or more of the enzymes involved in the cycle. Details on the inhibition of the glycolytic cycle during freezing and storage are rather scarce (Heen and Borgstrom, 1964).

d. Protein denaturation.--During thawing, tissue fluids exude from fish muscle. This is generally known as drip or expressible fluid. This fluid is released from ruptured cells, and contains nitrogen which appears to be

derived entirely from myogen of the muscle cells. A further release of free water is a sign of the denaturation of protein. This denaturation decreases with the lowering of the storage temperature.

e. Microbiological aspects.--Frozen fish contains a varying number of bacteria, depending on the number of microorganisms originally present in the raw material. Freezing causes an initial drop in the number of bacteria present in the order of 60 to 90%, and provided, the storage temperature is below the minimum for growth, there is an exponential, followed by a more gradual, decline during storage. The heavier the initial load, the greater will be the number of survivors. Repeated freezing and thawing is more lethal to bacteria than a single freezing and storage for the same time interval (Shewan, 1953).

Borgstrom (1955) found that slow freezing was also as effective as rapid freezing in inhibiting the growth of bacteria, but slow freezing should not be preferred because the bacteria may get time to develop and grow before the temperature becomes inhibitory. Use of fresh material and sanitation are essential to keep down numbers of bacteria.

f. Loss of flavor.--Fish that are quick frozen, heavily glazed and stored under best conditions keep for months and retain their edible qualities. Yet when storage is unduly prolonged, they become insipid. The chemical reason for the loss of flavor is probably the evaporation of

volatile constituents. Rancid flavor is also caused by the oxidation of fats. Various antioxidants like ascorbic acid, chlortetracycline (CTC) etc., can be used in small quantities to stop or retard this. See also Tomiyasu and Zenitani (1957).

2. Canning.--It is a means of fish preservation by destroying substantially all the microorganisms by the action of heat. The process essentially includes: cleaning the material, blanching, exhausting to exclude all air, sealing in "C-enamel"-lined tin cans, heat processing and cooling the cans rapidly (Jarvis, 1943). If properly done, the product may remain good for several years. The hygiene of the canning plant is an important consideration. Proper determination of heat penetration is also essential (Hess, 1956; van den Broek, 1964; Tanikawa and Doha, 1964).

3. Dehydration.--It implies literally the removal of water which is carried out in apparatus in which air currents and heat are produced artificially and the relative humidity is kept under control (Jason, 1964). In an artificial drying kiln, the water content is reduced in a few hours to well below the level of 15% on a fat free basis which is the minimum at which molds will grow. The drying temperature usually ranges from 104 to 115°F. The advantage of artificial drying is that the material can be reconstituted into a product resembling the original fish flesh merely by soaking in water. As the process is rapid,

bacterial growth is arrested during processing. The Torry Kiln, an artificial dryer designed by the Torry Research Station, Aberdeen, Scotland, is suitable for this purpose.

General Problems of Fish Preservation in Pakistan

1. Temperature.--One of the greatest difficulties in fish preservation in Pakistan is high atmospheric temperature (see Table 3, page 7). As already emphasized, bacteria multiply at a greater rate with the increase in temperature.

2. Humidity.--Coupled with high temperature, there is a high relative humidity. The high moisture content of the air makes sun-drying, smoking, and subsequent storage of the cured product difficult. In humid climates, dried products absorb moisture from the atmosphere thus making it favorable for bacterial growth.

3. Hygiene.--In a warm humid climate it is imperative to maintain a high standard of hygiene and sanitation in handling fish. Contaminated water supply, prevalence of flies, and other vermin as well as the difficulties of dealing with the untrained laborers are all factors which demand particular attention if outbreaks of food poisoning and infection are to be avoided (Borgstrom, 1962; Doha, 1963; Makato, 1959; Shewan, 1962).

Suggestions for Improvement

1. As far as temperature is concerned, the first step in this direction should be to chill the fish in ice and insulate the fish boxes used in transporting iced fish. The temperature of fish should be maintained at about 32^oF. Sanitation of fish boxes like disinfecting, cleaning, washing and drying before use and reuse should be practiced (Spencer, 1961).

2. Dehumidification is not an easy job. To protect the dried product from absorbing air borne moisture, polyethylene, laminated cellophane or aluminum foil can be used for packaging. Packaging should be complete and airtight.

3. The most important step seems to educate the fishermen and fish curers to respect codes of sanitation, hygiene, and public health. The primitive processes of preservation should gradually be replaced by modern methods.

D. Transport and Marketing

East Pakistan

Fish is an indispensable item of the daily diet of more than 90% of the people of this province. It is, therefore, of paramount importance that sufficient quantity of high quality fish should be made available to the people at reasonable prices. The supply of fish, in general, is inadequate in those places which are away from the fishing

centers.

This insufficient supply of fish is not due to shortage or lack of fishery resources in the province but to lack of suitable and adequate means of transport and marketing facilities. This leads to spoilage, maldistribution and reduction of catch. This also results in sun-drying of a large part of the catch near the fishing grounds. As the demand for dried fish is smaller than the fresh fish, most of it is exported. The main export markets are Ceylon, India, Hong Kong and other countries of East and Southeast Asia.

There is no modern fish handling yard or landing jetty in East Pakistan. Usually, the fish merchants select a place on the bank of a river or a canal where the fish consignments are to be brought by the river boats. This place usually lacks sanitary arrangements, electrification and protection from either the sun or rain. Handling is done by the fishermen themselves who often crush and twist the fish in their efforts to fill the fish boxes, baskets or jute bags to the fullest capacity with or without ice.

Fish is taken to the markets by a variety of ways such as head-loads, bullock carts, rickshaws, motor trucks or buses, motor launches, railroads, ships and manually operated river boats. The great majority of the chief fishing centers are far from port towns or railroad stations, being often 80-100 miles away. Inland catches are delivered

to the port towns and railroad stations mainly by the slow-moving river boats. Frequently, it takes six to seven days for the fish to reach the retail markets, and when it arrives, it is often in an advanced stage of spoilage thus becoming unfit for human consumption. During the monsoon, when the weather is stormy, the boats often have to wait at anchor for several days. Sometimes, to ensure the safety of the boats, the entire load has to be thrown away.

The consignments sent by railroad usually go by the slow passenger trains. These have no insulated or refrigerated vans. Moreover, the service is not organized to deal expeditiously with such perishable commodities as fish which are often subject to delays and consequent spoilage.

There are no standard containers for the transport of fish. Jute bags, wooden boxes and bamboo baskets of various shapes and sizes are used in transporting fish. Live fish is usually transported in four gallon kerosene oil tins; sometimes it is carried in waterfilled compartments of the river boats. For long distances boxes are generally used. The Railroad authorities require that the boxes should be of the following sizes: 27" x 21" x 18" for loads not exceeding 266 pounds; 30" x 24" x 18" for 328 pound loads; and 33" x 24" x 21" for 410 pound loads. However, since the boxes are made of a variety of materials, their weight varies considerably. Furthermore, as there is no fixed quantity of fish which can be put into boxes of a

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particular size, attempts are made to squeeze as many fish into them as possible, regardless of the damage caused in the fish. In fact, the total weight of a box of fish with ice may vary from 490 to 570 pounds. It is very difficult for the porters to handle the heavier loads. The boxes and baskets are not washed or disinfected, consequently they always smell and also hasten the decay of the fish packed in them.

The inadequacy of cold storage, the low output of ice and the distances between ice factories and the fishing and marketing centers make ice very costly. It is usually one dollar per block of 150 pounds. The expensiveness of ice is the main reason why the fishermen use such inadequate quantities of it, even though such a practice leads to spoilage of the fish and correspondingly low prices for the catches.

Wet, ordinary ice is the only preservative used in transporting the fish over long distances. The ice is crushed manually with wooden mallets, and when tightly packed into the boxes, the sharp edges injure the skin of the fish and cause early putrefaction. Moreover, fish preserved in this way is often disliked by the consumers.

The fishermen of East Pakistan are illiterate, poor and hard-pressed. They are always indebted to money lenders, or the fish merchants, who advance money to them against the exclusive right to buy all their catches at a fixed price.

The fish merchants constitute a very closely-knit monopolistic group and do not allow others to enter the business.

Between the fishermen and the fish merchants one or two groups of additional intermediaries often operate. First, there are the "nikaris" or carriers who go to the fishing areas and buy the catches, on the spot, at very low prices. Through the nikaris the fishermen frequently obtain advances from the fish merchants and consequently they only sell their fish to one particular nikari.

The nikaris carry the fish from the fishing grounds in their own boats to the assembly centers where they sell it to another agent, known as the "chalani" or despatcher. The chalanis also may only be agents of the merchants who actually advance money to the fishermen. The chalanis pack the fish and send it to merchants in the cities. These are known as "aratdars" or commission agents. The aratdar, on receipt of the consignment, disposes it by auction to the wholesalers, deducts his commission before paying the proceeds from the sale to the chalani. The wholesalers then sell the fish by negotiation with the retailers.

The fish thus passes through a great number of intermediaries before it reaches the consumer. Each has to derive a profit for his services; retail prices are usually high in relation to the price received by the fishermen.

There are no regular fish markets in the rural areas of East Pakistan. A fair, known as "hat" is held once or

twice a week in a centrally located village, usually on the bank of a river or canal. Here all kinds of commodities are bought and sold, together with fresh and dried fish.

In village towns, fish is sold by merchants carrying it in head-loads. In cities fish is sold daily but rarely are there any modern fish stalls. As a rule, the fish is sold in general markets. These are open spaces either covered with a permanent or temporary roofing of reeds or left uncovered. The floors are of brick, surfaced with a thin layer of plaster. There are no arrangements for cold storage, and only in a few cases are there proper facilities for displaying and dissecting the fish. As a general rule, there are no sloping platforms, no water supply, no facilities for drainage, washing and disinfection. The markets always smell and are infested with flies. Most of the markets are privately owned and there is no practical intervention by the Government.

The retail selling price is usually established by bargaining for every unit of sale. In cities, the sales unit is normally the "seer" (2 pounds). In small towns fish is chiefly sold by the piece. The prices vary with the season, and according to the size, quality and freshness of the fish and the distance between landing and disposal centers.

West Pakistan

The transport and marketing facilities for fish in this province are generally similar to those prevailing in East Pakistan. The system of marketing is characterized by the existence of a greater number of intermediaries and by the absence of any organized cooperation on the part of either fishermen or consumers. See further Jaleel (1955); Ericksen (1958).

Suggestions for Improvement

In order to improve the state of the fish industry in general and of marketing in particular the following measures are necessary:

The most important is the betterment of the living and working conditions of the fishermen, for without this, little lasting success is likely to be achieved. For this purpose, the organizations of fishermen's cooperative societies seems to be the best solution. The cooperatives should supply gear, sail cloth, yarn and other requirements as well as credit to the fishermen. They should gradually perform some of the marketing functions in order to reduce the number of intermediaries in fish distribution.

Well-designed harbors and landing jetties are needed. At every important landing center a properly constructed handling yard as well as cheap ice, mechanical ice-crushers and cold storage facilities should be provided. Modern

hygienic fish curing yards need to be established at appropriate places in the fishing areas. In this way wastage of fish, amounting to 15% during the winter and 90% during mid-summer, could be considerably reduced (Jaleel, 1955).

Fishing settlements and landing centers should be linked with the wholesale markets by good motor roads wherever possible. At the important assembly centers insulated or refrigerated transport lorries of one ton capacity should be provided. In the riverine parts of the country, fast moving craft with ice holds or insulated cabins would be valuable. Two types of water craft, the larger for the estuarine fisheries and the smaller for carrying fish from the inland fisheries might well be introduced.

Arrangements need to be made with the railroad and the steamer authorities for the provision of insulated vans and cold storage facilities in trains and ships, and, in some cases, for the running of special services. Steps should be taken to introduce special rates for the carriage of fish by the railways. Instructions would have to be issued to all railroad officials to book the fish consignments, immediately on receipt, by the first available train. Railroad and steamer staff should be encouraged to give special attention to fish traffic and instructed in the most efficient and expeditious methods of handling it in transit.

Cheap fish boxes of standard size and specification, strong but light for easy handling, should be introduced and the merchants directed to use only these boxes, and to keep them clean and disinfected after each trip. The maximum weight of fish and ice, as well as the weight of the box itself, should be fixed so that the merchants do not try to cram too much fish and ice into the boxes, without any regard to the condition of the fish. The use of jute bags should be discouraged.

Wholesale and retail markets on modern lines should be provided, at least in the big cities which consume large quantities of fish. Arrangements should be made there for the provision of cold stores for preserving both fish and ice. In the important cities model retail shops could be opened by the Government, to raise the standard of marketing and the quality of the product sold. By measures such as these the consumption of fish would be encouraged.

E. Consumption

The average per capita consumption of fish is estimated at 10 pounds per year in Pakistan but the actual consumption varies between different parts of the country. In the coastal area of West Pakistan, the average annual consumption per head reaches 30-35 pounds whereas in the Karachi area and in East Pakistan it is 8 pounds, in Khairpur and Sind 5.4 pounds, in the Punjab 0.24 pounds, and in the

interior of Baluchistan it is only 0.025 pounds (Jaleel, 1955). In some localities, however, the demand for fish is almost nil which may be attributed to a lack of knowledge regarding the value of fish as a protein food. It is even believed by a group of people that the consumption of fish lends to certain skin diseases. Some people do not eat catfish and shellfish on religious and other grounds.

Besides increasing the production of fish through scientific means coupled with improved methods of handling, preservation, transport and marketing, the consumption of fish may be augmented by adopting the following measures:

- a. Publicity through periodicals, press, radio and movies. See further Organization of European Economic Cooperation (1957, 1959).
- b. Handbooks giving various recipes for the preparation of proteinaceous fish diet (Baeder and Tack, 1946; Tack et al., 1947).

F. Nutritive Value

Early systematic investigations of the nutritive value of fish stimulated by the meat shortage that occurred during World War I were made possible by the concurrent development of adequate analytical feeding methods. The early experiments found that the nutritive value of fish was equal to that of meat and also recognized that fish oil represents a good source of calories and provides many important

vitamins. The value of fish increased particularly in the "twenties" and "thirties" when it was established that fish contained large amounts of the newly discovered vitamins A and D. But due to the increased production of calorie resources in the form of more palatable and less expensive vegetable and animal oils, and the introduction of synthetic vitamins, the nutritional importance of fish today rests largely on the fact that it is an excellent source of protein of high biological value (Geiger and Borgstrom, 1962).

Recent medical investigations have shown that insufficient intake of protein or the consumption of protein that failed to provide the essential amino acids are most significant factors in human malnutrition and that a supply of suitable protein is the chief limiting factor of good nutrition. In addition, the breeding of commercially important animals depends upon the quality and quantity of dietary protein. Consequently, the recognition that fish contain proteins or superior nutritional properties places them in an especially important category of foods.

In order to evaluate fully the nutritive value of fish protein, it is desirable to establish its amino acid composition. A comparative estimate of essential amino acid content of the edible portion of fish and some other foodstuffs is given in Table 12. Fish proteins contain relatively great portions of lysine, threonine, methionine and tryptophan which are relatively low in cereal diet.

TABLE 12. Comparison of essential amino acid content of fish with some other foodstuffs

Amino Acid	Fish ^a (edible portion)	Cow's milk ^a (whole)	Hen's egg ^a (whole)	Beef ^b (muscle)	Rice ^c (milled)	Wheat ^d (flour)
			g amino acid/100 g. protein			
Arginine	8.27	3.5	6.4	6.88	9.0	3.9
Histidine	2.63	2.4	2.1	3.43	3.1	2.2
Isoleucine	6.00	6.6	8.6	5.37	4.8	4.2
Leucine	9.72	11.8	9.2	8.14	8.0	7.0
Lysine	9.72	8.1	7.2	10.13	3.7	1.9
Methionine	2.63	2.2	4.1	2.58	3.3	2.0
Phenylalanine	4.45	4.6	6.3	4.38	4.4	5.5
Threonine	5.18	4.8	4.9	5.06	3.9	2.7
Tryptophan	0.81	1.4	1.5	1.06	1.3	0.8
Tyrosine	2.54	6.2	4.5	2.85	4.1	3.8
Valine	6.54	7.0	7.3	6.97	7.1	4.1

^aSénécal (1958).^bWilliams (1955).^cKik (1956); Balasubramanyan *et al.* (1952).^dBlock and Bolling (1951); Balasubramanyan *et al.* (1952).

Note: See also FAO (1957) for the estimation of mg. amino acid/g N of the above items.

Experiments showed that sun-dried rohu (Labeo rohita) meal has higher biological value and digestibility coefficient than steam-dried fish meal (Basu and De, 1938a). The digestibility and biological value of fish proteins are very high varying between 83-97 and 70-88% respectively (Basu and Gupta, 1939). It has been further shown that even at 5 and 10% levels, the biological value of some Bengal fresh-water fish (Saccobranhus fossilis, Mystus aor, etc.) is higher than casein (Saha, 1940).

Extraction and chemical analysis of proteins of rohu, and hilsa (Hilsa ilisha), revealed the difference in the nutritive value of the proteins of these two species of fish. Rohu proteins contain more of the sulfur containing amino acids such as methionine and cystine than the proteins of hilsa (Basu and De, 1938b).

Saha and Guha (1939, 1940) studied 37 species of fresh-water fish of East Pakistan and West Bengal (India) in regard to their nutritive values. They found that the catfish (Saccobranhus fossilis) has the highest protein content (22.8%) followed by hilsa with 21.8%. The major carps (Catla catla, Cirrhina mrigala, Labeo rohita and L. calbasu) contain 19.5, 19.5, 16.6 and 14.7% protein respectively in their flesh. Hilsa is the richest source of fat (19.4%), followed by Silonia silondia, Pangasius pangasius, Barbus sarana and Anabas testudineus with 12.1, 10.8, 9.9 and 8.8% respectively. The gray mullet (Mugil corsula) has

the highest calcium content (1.05%) being followed by Labeo rohita and Saccobranthus fossilis with 0.67% and 0.67% respectively. The gray mullet is also the richest source of phosphorous (0.7%). As regards total iron content, S. fossilis heads the list with 226 mg./100 g. of the raw fresh fish followed by the gray mullet with 205 mg./100 g.

Fish Liver Oil

Seshan (1940) has reviewed the vitamin A content of the body and liver oils of 62 species of fresh-water and 36 species of salt-water fish of Bengal. Considerable seasonal variations occur with rohu (Labeo rohita), its mesenteric fat contains no vitamin A (Chakravorty et al., 1933). The vitamin A potency of hilsa liver oil is equal to that of halibut liver oil (48,000 I.U./g.) (Nag and Banerjee, 1933). See also Chakravorty et al. (1933); Ghosh et al. (1933); and Ghosh and Guha (1935). The methods of vitamin A assay, biological, tintometric and spectrographic, give fairly concordant results (Basu et al., 1940). The vitamin A potency of the liver oils of rohu and hilsa is reported to be 461 and 120 I.U./g. as determined by the biological method (Basu and De, 1938c). The liver oils of four common fresh-water species of fish (Mystus aor, Wallago attu, Labeo rohita and Rita rita) have also been found to be rich sources of vitamin A with 26,000, 24,000, 11,000 and 21,000 I.U./g. of oil (Ahmad et al., 1945).

Spectrographic analysis has shown that most of the vitamin A₂ in the liver oils of the three common fresh-water fish, Callichrous bimaculatus, Ophicephalus striatus and Wallago attu, is found in the ester form, while vitamin A₁ existed as alcohol (Balasundaram et al., 1955).

Hilsa liver oil is a very poor source of vitamin B₂. The extraction of this vitamin was optimum at pH 5 (Guha and Chakravorty, 1933).

Vitamin D potency of the body and liver oils of a few common fishes of Bengal was found to be as high as 52 rat-, and 93 chicken units per gram (Basu and Sen Gupta, 1940). Values, on the whole, are very small as compared to the antirachitic potency of cod liver oil. Crystalline vitamin D has been isolated from the body oil of Notopterus chitala; the properties of the crystals agree fairly closely with those of calciferol (Basu, 1934).

III. FISH CULTURE

A. General

Fishing, however mechanized it may be, is still the chase of wild creatures. It is the last and greatest of Man's activities as a hunter. If fishing is hunting, then fish culture is stock-raising. Here there is no question of ownership or property rights as in the case of fishing in the high seas, for the fish are raised in natural or artificial ponds which are owned by someone and the fish he grows are his property as much as a ranch and its cattle is the property of the rancher. He can therefore afford to improve his fish stocks, and to lay out money in fertilizers and fodders for them, for he who has spent the money reaps the profit.

Hickling (1959) has defined fish culture as follows:

Fish culture has the same object as agriculture and stock-breeding, namely, to increase by all possible means the production of food far above the level which would be produced naturally. Like agriculture, fish culture includes the elimination of unwanted plants and animals, their replacement by desirable species, the improvement of these species by cross breeding and selection, and the improvement of the substratum by the use of fertilizers.

Fish culture can make productive use of lands and water which may be unsuitable for agriculture and irrigation. It has a definite place in land and water usage and the weight of fish produced can be made very great by proper

management as is practiced in China and Israel. Borgstrom (1961b) states that in the USSR the rate of fish production in ponds has tripled in the last decade and that even as far north as the 60th parallel of latitude, fish crops of the order of 410 kg. per hectare per annum can now be raised. This is a notable achievement in an area where the period of fish growth annually is very short. Fish raising is said to give larger returns generally, in money and food, than the raising of cattle, sheep and poultry. Because of this high rate of fish production per unit of area, as compared with much lower rate of production in natural waters, it is considered feasible to produce as much fish in fish ponds in Russia as from all the inland waters including the Sea of Azov.

Fishes are good converters of organic substances into high grade animal protein. Fish culture has an important part to play in supplying that animal protein which is so much needed in Pakistanis' diet (FAO, 1954, 1957).

Fish culture is a very efficient form of animal husbandry which can produce up to four metric tons of flesh per acre per annum (as in China) which is due in part because fish do not use energy in supporting themselves, for their bodies are supported by the water, and they do not lose calories in maintaining a constant body temperature. They can usually feed on a wide range of fodders and are valuable scavengers (Hickling, 1962).

The efficiency of a tropical inland fish culture system is, according to Hickling (1961), not only due to the high mean temperatures which accelerate all life processes of cold bloods including the whole chain of events which leads to the growth and reproduction of fishes, but also to the abundance of herbivorous fish with the shortest, swiftest, and least wasteful food chains. Therefore, a given body of water producing a given amount of primary food material can support a manifold population of fish as compared with temperate climates.

B. Historical

The origin of fish culture in Pakistan which is conducted in fresh and brackish-water ponds, lakes, swamps, reservoirs and rice fields is largely unknown. In East Pakistan, fish culture is conducted on an extensive scale especially in domestic ponds which are found with almost every home. Undoubtedly, the industry must have been developed thousands of years ago, as is evidenced by the extensiveness and antiquity of the practices. In Chanakya's "Arthasastra" or Economics, written somewhere between 321 and 300 B.C., a secret means of rendering fish in a reservoir poisonous during war has been described which would appear to show that fish culture was practiced more than 2,000 years ago. Khona, the daughter-in-law of Varahamihira, recommended the cultivation of vegetables on the banks of

ponds. King Someswara of Chalukya Dynasty described methods of fattening fish in the chapter on 'Matsyavinoda' or Sport Fishing in his encyclopedic work 'Manasollasa' or Happiness of Mind which was compiled in A.D. 1,127. These are the clear indications of the antiquity of fish culture in the Indo-Pacific subcontinent (Hora and Pillay, 1962). Lin (1940), however, quotes authors who consider that fish farming was already in practice in China as far back as 2,000 B.C. But, Fan Lai was the first to describe the techniques of carp culture in China in 475 B.C. It is not surprising to learn that the earliest records came from China, as fish culture, like any other forms of husbandry, flourishes only under settled conditions which have been on record in China for 4,000 years. See also Drews (1952, 1961).

Fish culture as a regular farm practice was not much in vogue in West Pakistan up until the end of the 19th century. During the British Rule, some sport-loving Englishmen tried to develop the culture of trout in some hill streams in Kashmir. After independence in 1947, fishery departments have been established in both the provinces of Pakistan and fish culture has been intensified. Considerable attention is being given to fish farming as a means of producing first class and, at the same time, cheap animal protein to feed the growing population.

C. Basic Ecological Principles

Successful fish culture aims at the production of the largest possible crop of good quality fish with the minimum expenditure of money, time and energy. Fish, as a group, are more economical to raise per unit area than higher animals (e.g., cattle), but the relative efficiency of the cultivated species differs in the conversion of the various forms of organic matter into the fish flesh. In this respect, the ecosystem and the food chains in aquatic situations need consideration.

1. The Ecosystem

Any area of nature that includes living organisms and non-living substances interacting to produce an exchange of materials between the living and the non-living parts is an ecological system or ecosystem. A pond is an example of an ecosystem. Functionally, a pond ecosystem has four basic units:

1) Abiotic substances. These are basic inorganic and organic compounds like water, carbon dioxide, oxygen, calcium, nitrogen, phosphorus salts, amino and humic acids, etc. The vital nutrients are, to a large extent, held in reserve in particulate matter (especially in the bottom sediments) and also in the organisms themselves. A small portion of these nutrients, however, is in solution and is immediately available to organisms. The rate of function

of the entire ecosystem is regulated, among other things, by the rate of release of nutrients from the solids (Odum and Odum, 1959). See also Rawson (1939); Wiebe (1930); and Hutchinson (1948).

2) Producer organisms. A pond may have two main types of producers: (a) rooted or large floating plants (macrophytes), and (b) minute floating plants, usually algae, called phytoplankton. The former grow generally in shallow water while the latter are distributed throughout the pond as deep as light penetrates. The growth of producer organisms is directly related to the fish productivity of the pond (Prescott, 1939; 1951).

3) Consumer organisms. These are animals such as insect larvae, crustacea and fish. The primary consumers (herbivores) feed directly on living plants or plant remains and are of two types, zooplankton and bottom forms. The secondary consumers (carnivores) feed on the primary consumers, etc.

4) Decomposer organisms. These are aquatic bacteria and fungi. They are distributed throughout the pond, but are especially abundant in the mud-water interface along the bottom where dead plants and animals accumulate. Though some bacteria and fungi attack living organisms (e.g., fish), the great majority are saprobic and begin attack only after the organism dies, releasing nutrients for reuse.

2. The Food Chain

The transfer of food energy from the source in plants through a series of organisms with repeated eating and being eaten is referred to as the food chain (Odum and Odum, 1959). At each transfer a large proportion of the potential energy is lost as heat. According to Birge and Juday (1922), the material that can be used as food by the zooplankton of Lake Mendota, Wisconsin, weighs 12-18 times as much as the weight of these species. McGinitie (1935) also estimated that 10,000 pounds of algae make 1,000 pounds of microcrustaceans, 1,000 pounds of these make 100 pounds of small fish, 100 pounds of small fish make 10 pounds of large fish which might go to form 1 pound of man. The number of steps in the food chain, called trophic levels, varies but is usually four or five. The shorter the food chain, i.e., the nearer the organism to the beginning of the chain, the greater the available energy which can be converted into biomass (= living weight, including stored food) and/or dissipated by respiration.

Starting with the macrophytes a number of food chains can be worked out in theory. The weeds may be eaten directly by the herbivorous fish or they may be eaten by various insect larvae which in turn will serve as food for insectivorous or omnivorous species of fish. The dead and decaying plant material will form part of the detritus, which will either be taken in directly by detritus feeders

like mrigal (Cirrhina mrigala) or else be eaten by detritus-feeding insects, which in turn form food for other fish (Figure 5). With the algae as the starting point, there are the algal feeders such as Tilapia mossambica which feeds on algae directly, or else zooplankton such as rotifers and small crustacea eat the algae, and in turn are eaten by those fish capable of dealing with the coarser plankton. The dead and decaying algae will form part of the general detritus which serves as food for other fish or for certain insect larvae (Figure 6). In all cases, the fish themselves may be eaten by predatory species such as the snakeheads (Ophicephalus spp.) or by fish-eating birds and mammals although this is not to be encouraged in ponds. The dead remains and feces at all stages will undergo bacterial and fungal action to release essential salts to the water and mud again. See further Prowse (1957).

3. Selection of Cultivable Species

The species to be selected should have a rapid growth rate and should be able to depend on the natural food supply in the pond or lake. The importance of shortening the food chain to achieve this is obvious. A fish which can convert decaying organic matter or algae directly into the edible fish flesh is, from the standpoint of food utilization, superior to those that cannot. This is the reason why herbivorous and detritus feeders like Catla catla, Labeo spp.,

Figure 5. A diagrammatic presentation of food chain in a fish pond starting with macrophytes.

Figure 6. A diagrammatic presentation of food chain in a fish pond starting with microscopic algae.

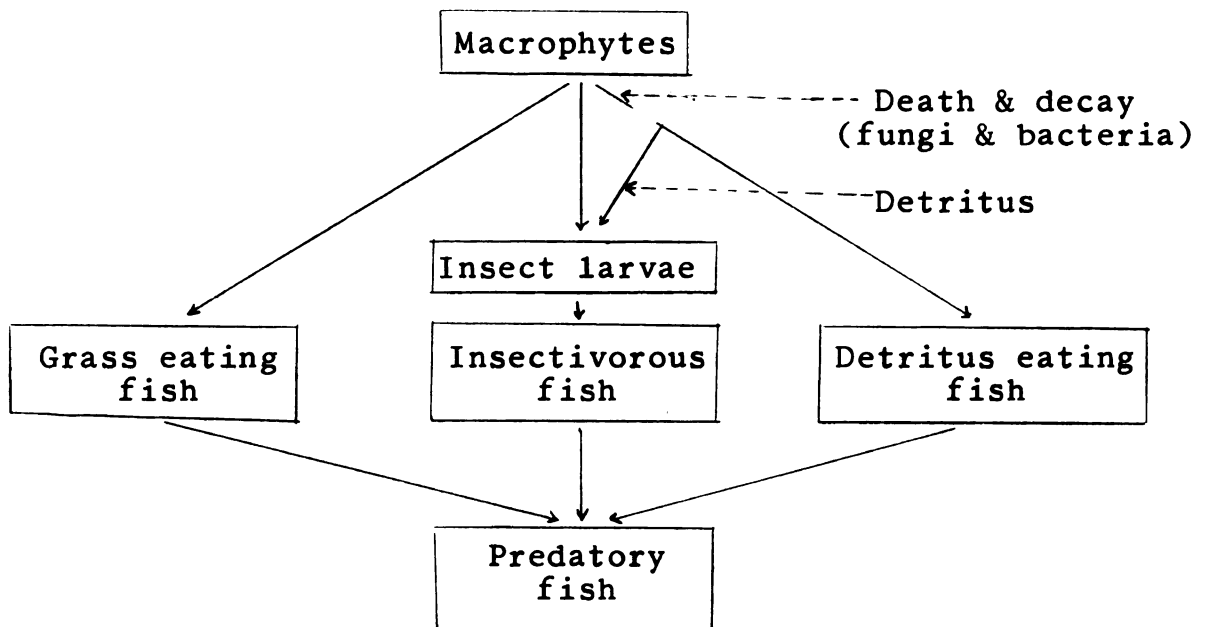


Figure 5

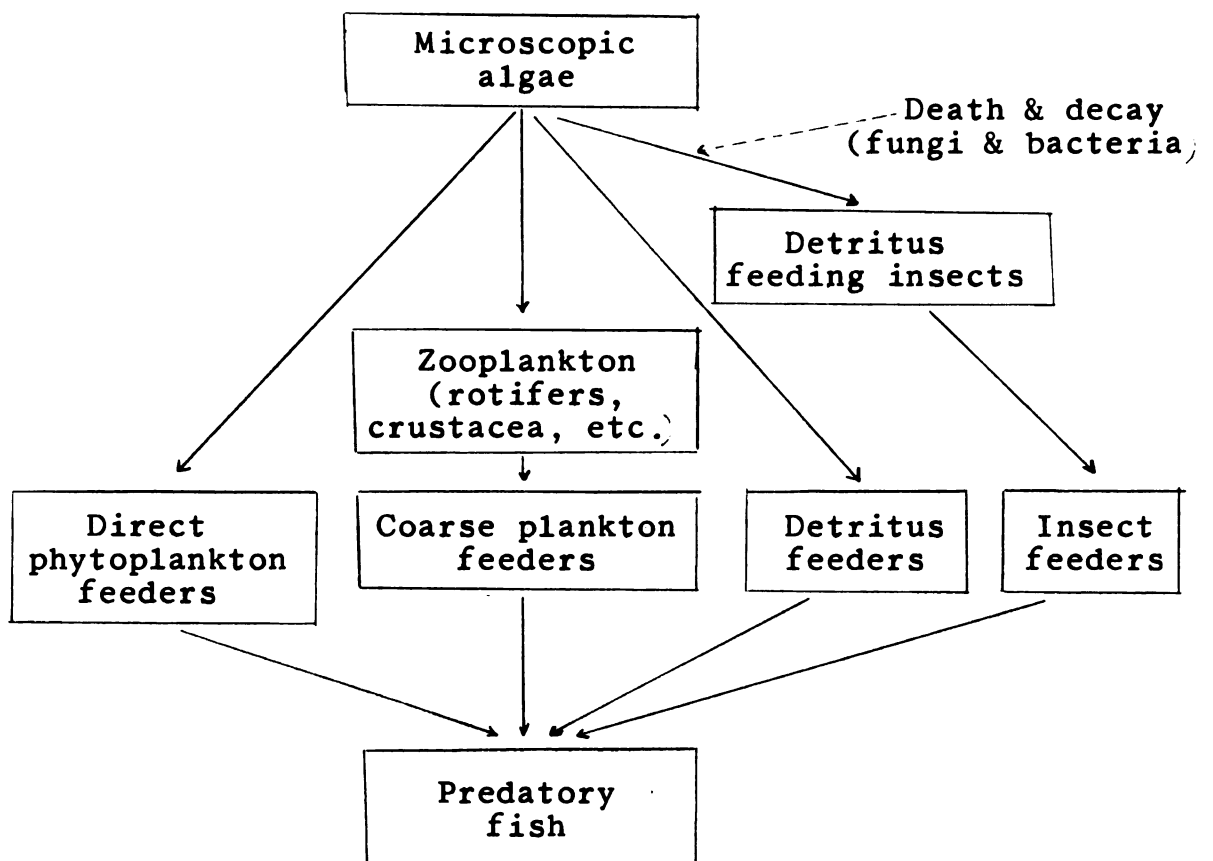


Figure 6

Cirrhina spp., Mugil spp., and Tilapia spp., are preferred by the Pakistani fish culturists. These fish are also tolerant of other species in the pond.

Utilization of available food resources in a pond should also be considered while selecting fish for culture. Pond fishes have distinct feeding zones and food preferences. Therefore, culture of a single species in a pond may not be profitable since it may not use all sources of food. See further page 161).

Even though the culture of non-predaceous fish is more profitable and economical, it may not be possible to restrict cultivation to those species in all areas. Human preferences form an important consideration in this respect. Carnivorous fishes help to maintain a balanced fish population in ponds and impoundments by checking the stunting in forage fishes, and thus contribute to the production of adequate quantity of food fish of the desired size (Swingle, 1950).

4. Introduction of Exotic Species

The major carps of Pakistan do not breed in ponds. Their fry are collected from spawning sites in rivers to be raised in ponds and impoundments. The supply of fry cannot be assured at the proper time and there is a difficulty in fry transport (see also page 100) resulting in about 40% mortality of fry with consequent high price (Schuster, 1951; Ahmad, 1956a)

The common carp (Cyprinus carpio), the gold fish (Carassius auratus) and the Chinese grass carp (Ctenopharyngodon idellus) can breed in closed waters. These carps and the gouramy (Trichogaster pectoralis), and the cichlid fish (Tilapia mossambica) have recently been released in Pakistan's fresh-waters. There is, however, a general apathy among hydrobiologists to the introduction of new species into a specific environment, because it is feared that they may compete with the established indigenous species and may upset the ecological balance of waters. There is a possibility that the exotic fish may escape from fish ponds into the rivers or other water areas where they can possibly affect the biotic relationships unfavorable to the indigenous fauna. Tilapia mossambica was brought to Pakistan from Thailand in 1954 and released in some ponds in Dacca on an experimental basis. It has established itself since then in East Pakistan and the Provincial Fisheries Directorate have distributed 1,032,288 Tilapia among various districts up to 1962. Over 241,000 young Tilapia have been released in open waters (FAO, 1959). Tilapia, a mouth breeder, reproduces three times a year in ponds and is herbivorous. Since it multiplies very rapidly, it tends to overpopulate and become stunted. No controlled experiments have so far been made to assess its influence on the local fauna. The wide introduction of this species can be recommended only when it is established as harmless or beneficial. The same holds true

for other exotic species. Preliminary experiments conducted in India (FAO, 1959) have shown that Tilapia is not desirable for extensive culture. It appears, however, to be of value as forage fish as indicated by experiments on the culture of snakeheads with Tilapia. However, in view of its quick growth and breeding in confined waters, it has become very popular with fish culturists. Preliminary experiments have shown that the growth of common carp (Cyprinus carpio) in experimental ponds is better than Cirrhina mrigala, as good as Labeo rohita, and slower than Catla catla (FAO, 1959).

5. Raising Euryhaline Fish in Fresh-waters

It has been found possible to transplant euryhaline fish into the fresh-waters of the coastal areas for cultivation. The fry of such fish as Mugil spp. and Lates calcarifer can directly be transferred into fresh-waters or they can be acclimatized to live in ponds by slow and gradual diminution of the salinity of the water. Intensive investigations along this line are needed to establish working values for responses.

There appears to be no common pond fish that can be raised throughout Pakistan. The efficiency of fish production varies with species and ecological factors. Extensive research and experimentation are needed to determine the species of fish that are best suited for each type of pond and the kind of food it prefers and on which it grows best. At the same time, economic aspects of the cultivable species of fish should also be stressed.

D. Cultivated Species

The following species of fish are raised in the inland waters of East Pakistan (Table 13).

Catla catla Hamilton (PLATE I, a)

This species is a fresh-water river carp attaining a maximum length of 1800 mm. and a weight of 6,750 g. It spawns during the monsoon (June to September) in rivers whence eggs and fry are collected for raising in ponds, lakes and reservoirs. It reaches sexual maturity when about 56 cm. long and deposits eggs in inundated, shallow marginal areas of rivers. The eggs are transparent, spherical, and 2 to 2.2 mm. in diameter. The eggs hatch about 18 hours after fertilization and attain adult characters in about six weeks. They are plankton and detritus feeder.

Labeo rohita Hamilton (PLATE II, c)

This is another fresh-water river carp attaining a maximum length of 900 mm. and a maximum weight of 5,400 g. It spawns like Catla in rivers during the monsoon. Eggs and fry collected there are raised in ponds. They are herbivorous.

Labeo calbasu Hamilton (PLATE I, b)

This is another fresh-water river carp attaining a maximum length of 900 mm. and weight of 4500 g. It spawns like Catla in rivers during the monsoon. The eggs hatch 17 hours after fertilization. The spawn collected in rivers are raised in ponds. Their adult characters are attained within 30 days. They are omnivorous.

TABLE 13. Classified list of cultivated species of fish in East Pakistan

Family	Scientific name	(F) or (B)*	(I) or (E)**
Cyprinidae	<u>Catla catla</u> Hamilton	F	I
	<u>Labeo rohita</u> Hamilton	F	I
	<u>Labeo calbasu</u> Hamilton	F	I
	<u>Labeo fimbriatus</u> Bloch	F	I
	<u>Barbus sarana</u> Hamilton	F	I
	<u>Barbus chola</u> Hamilton	F	I
	<u>Cirrhina mrigala</u> Hamilton	F	I
	<u>Cirrhina reba</u> Hamilton	F	I
	<u>Cyprinus carpio</u> Linnaeus	F	E
	<u>Carassius auratus</u> Linnaeus	F	E
Siluridae	<u>Wallago attu</u> Bloch and Schneider	F	I
	<u>Clarias batrachus</u> Linnaeus	F	I
	<u>Saccobranhus fossilis</u> Bloch	F	I
Ophicephalidae	<u>Ophicephalus marulius</u> Hamilton	F	I
	<u>Ophicephalus punctatus</u> Bloch	F	I
	<u>Ophicephalus striatus</u> Bleeker	F	I
Anabatidae	<u>Anabas testudineus</u> Bloch	F	I
Osphronemidae	<u>Trichogaster pectoralis</u> Regan	F	I
	<u>Colisa fasciata</u> Bloch and Schneider	F	I
Cichlidae	<u>Tilapia mossambica</u> Peters	F	E
Mugilidae	<u>Mugil tade</u> Forskål	B	I
	<u>Mugil parsia</u> Cuvier and Valencienns	B	I
	<u>Mugil cephalus</u> Linnaeus	B	I
	<u>Mugil corsula</u> Linnaeus	B	I
Latidae	<u>Lates calcarifer</u> Bloch	B	I

* (F) = Fresh-water; (B) = Brackish-water.

** (I) = Indigenous; (E) = Exotic.

Labeo fimbriatus Bloch

This is another fresh-water river carp attaining a maximum length of 900 mm. and weight of 4500 g. It spawns like Catla in rivers during the monsoon. Spawn collected in rivers are raised in ponds. They are plankton and detritus feeder.

Barbus sarana Hamilton

This is also a fresh-water river carp attaining a maximum length of 760 mm. It spawns like Catla in rivers during the monsoon. Spawn is collected in rivers and raised in ponds. They are plankton and detritus feeder.

Barbus chola Hamilton

This is another river carp attaining a maximum length of 260 mm. Other characters of this fish are not reported.

Cirrhina mrigala Hamilton (PLATE I, c)

This is another fresh-water river carp attaining a maximum length of 1,000 mm. and weight 4,000 g. It breeds in rivers during the monsoon. The eggs hatch in about 18 hours after fertilization and adult characters are attained in three weeks. It is omnivorous.

Cirrhina reba Hamilton

This is another fresh-water river carp attaining a maximum of 300 mm. It breeds in rivers like Catla. The eggs measuring 2.8-3.2 mm. in diameter hatch about 15 hours after fertilization. Spawn is collected in rivers and

raised in ponds when fry of major carps are unavailable. It attains sexual maturity within a year. It feeds on plankton and detritus.

Cyprinus carpio Linnaeus

It is a fresh-water exotic carp. It is being cultured experimentally in East Pakistan. It spawns in confined waters at the beginning of the monsoon. The eggs are yellow and adhesive and are laid on aquatic plants. They hatch in about two to three days. It is omnivorous.

Carassius auratus Linnaeus

It is another exotic fresh-water carp attaining a maximum length of 450 mm. It can breed in ponds or other confined waters throughout the year. It lays adhesive eggs on aquatic plants which hatch within four days. It is possible to cross it with Cyprinus carpio. It feeds on plankton and detritus.

Wallago attu Bloch and Schneider (PLATE III, d)

This is a fresh-water catfish attaining a maximum length of 1,500 mm. It spawns during the monsoon in rivers and channels. The eggs measuring 1.2-1.5 mm. in diameter hatch in about 17 hours. It has an extremely carnivorous habit and is unfit for culture with carps. It is reared in swamps and marshes.

Clarias batrachus Linnaeus (PLATE V, a and b)

It is another fresh-water river catfish attaining a maximum length of 400 mm. It breeds in confined waters throughout the year. It often occurs as extraneous fish in

ponds, lakes, swamps and rice fields. It has labyrinthiform accessory respiratory organs and can withstand very low oxygen concentration. It is omnivorous.

Saccobranthus fossilis Bloch (PLATE III, e)

This is another fresh-water catfish attaining a maximum length of 450 mm. It breeds in ponds and other confined waters throughout the year. It also occurs in ponds as extraneous fish. It can withstand, like Clarias batrachus, extreme conditions such as low concentration of oxygen (i.e., less than 2 p.p.m.). It has accessory respiratory organs like those of Clarias. It is omnivorous.

Ophicephalus marulius Hamilton (PLATE III, a)

This is a fresh-water snakehead fish attaining a maximum length of 1,200 mm. During the monsoon, it breeds freely in ponds and swamps. The eggs measure 1.5 mm. in diameter. The young become independent of parents in about six weeks. It is carnivorous.

Ophicephalus punctatus Bloch (PLATE III, b)

This is another fresh-water snakehead fish attaining a maximum length of 300 mm. It breeds in ponds and rice fields during the monsoon. It builds nest and gives parental care to the young. It can live in water with low oxygen concentration with the help of accessory respiratory organs. It is carnivorous.

Trichogaster pectoralis Regan

It is a fresh-water gouramy which breeds and grows rapidly in rice fields. It attains a maximum length and weight of 250 mm. and 140 g. respectively. Its eggs hatch within two days. It is a plankton and detritus feeder.

Colisa fasciata Bloch and Schneider (PLATE IV, a)

It is also a fresh-water gouramy. It is larvivorous in habit. Its other characters are not reported.

Tilapia mossambica Peters (PLATE V, c and d)

It is a fresh-water exotic fish belonging to the family Cichlidae. It attains a maximum length and weight of 300 mm. and 450 g. It breeds in confined waters prolifically throughout the year. The male fish builds nest at the bottom of the pond and the female lays 75 to 250 eggs. The eggs are taken into the mouth of the female as soon as they are laid. They hatch in three to five days. It can also be cultured in brackish-water ponds (Chacko and Krishnamurthi, 1954; Chen, 1953; Chimits, 1955, 1957). It is a plankton feeder.

Mugil tade Forskål

It is a brackish-water mullet which is easily adaptable to fresh-water ponds. It attains a maximum length of 700 mm. It does not breed in ponds. Its fry are collected from coastal waters and raised in ponds. It is herbivorous.

Mugil parsia Cuvier and Valencienns (PLATE VI, b)

It is another brackish-water mullet easily cultivable in fresh and brackish-water ponds, lakes and swamps.

Like M. tade it does not breed in confined waters. Its fry and fingerlings are collected from estuaries. It attains a maximum length of 400 mm. in ponds.

Mugil cephalus Linnaeus

It is another mullet which is cultured in brackish to fresh-water ponds. It attains a maximum length and weight of 500 mm. and 1,300 g. respectively. It also does not breed in confined waters. Its fry are collected from estuaries from December to March. It is a plankton feeder.

Mugil corsula Linnaeus (PLATE VI, a)

It is also another mullet cultivated in ponds in coastal districts. It attains a maximum length of 450 mm. It spawns in rivers during the monsoon; its eggs are pelagic and semibuoyant and measure 1 mm. in diameter. It is herbivorous.

Lates calcarifer Bloch (PLATE II, d)

It is a brackish-water perch attaining a maximum length of 1,700 mm. and weight of 5,000 g. It often occurs as extraneous fish in ponds in coastal districts. It does not breed in ponds. The fry are collected from rivers, creeks and lagoons. It is extremely carnivorous.

1. Breeding Habits and Requirements

Some cultivated fish show parental care, others do not. The snakeheads, the gouramis and some catfishes like Mystus aor build nests and guard the young. Tilapia protects its eggs in the buccal cavity. Fish showing parental

care do not show high fecundity and some such as Tilapia breed thrice a year. Their progeny have a high rate of survival; while fish, such as the major carps, showing no parental care, have high fecundity in order to compensate for the loss of the eggs or the young due to predation or other natural causes (Table 14).

According to Hubbs and Eschmeyer (1938), the following conditions have been found favorable for spawning of lake fishes:

- a. A water level stable enough to avoid drying of eggs or fry or subjecting them to either abnormally shallow or deep waters.
- b. A water level which covers the spawning grounds to a proper depth, whether these grounds be gravel bar or bulrush patch or a marsh.
- c. Favorable chemical conditions in the water covering the spawning beds, particularly a high content of dissolved oxygen.
- d. Relatively constant temperature, not rising high enough to harm the eggs and not dropping low enough to kill the fry or to drive the fish off their beds before the spawning or the guarding of the eggs is completed.
- e. Temperature low enough or high enough (depending on the species involved) for the fish to spawn normally.

TABLE 14. Comparative fecundity of some major carps

Name of species	Total weight	Number of eggs produced	Ratio of number eggs to total weight of species	Reference
	(g)	(1,000)		
<u>Labeo rohita</u>	4,653.5	1,905.0	409.3	Khan (1934, 1947)
<u>Labeo calbasu</u>	1,816.0	739.4	409.3	Khan (1934, 1947)
<u>Labeo bata</u>	1,049.9	300.0	285.5	Alikunhi (1956)
<u>Cirrhina mrigala</u>	1,475.5	216.8	146.9	Khan (1934)
<u>Catla catla</u>	5,107.5	400.3	78.3	Khan (1934, 1947)

- f. Waters relatively free from smothering silt, whether caused by waves and currents, by motor boats or by wading. A coating of silt is harmful to fish eggs.
- g. Spawning beds relatively free from disturbance by motor boats or bathers.
- h. Protection from fishing during at least the height of the spawning season, and
- i. A sufficient area of the proper bottom material to deposit the eggs, at suitable depths and in places adequately protected from wave action.

As already mentioned, the cultivated carps of Pakistan do not breed in confined waters. They breed in fresh-water rivers during the South-West monsoon from June to September. Ahmad (1945a, b), Hora (1945a) and Khan (1942) observed that the monsoon flood is the principal determining factor in the spawning of carps. Keeping in view the observations of Hubbs and Eschmeyer (1938), the following observations may be made on the effects of floods on the spawning of Pakistan's major carps.

- a. A heavy flood indicates more or less that the monsoon conditions have set in properly and that a water level stable enough to avoid drying the eggs has been established in the marginal areas where the spawn is liberated.

- b. The flood also ensures that the actual breeding grounds have been covered to a suitable depth.
- c. Rushing water after a torrential rainfall will also ensure a high content of dissolved oxygen in the water covering the spawning beds.
- d. It has been observed experimentally (Hora, 1945a) that the temperature of water in which the brood fish are kept may rise high but after a heavy shower, the temperature comes down and then the fish begins to spawn. For a considerable period after a heavy shower, the temperature remains relatively constant, not rising high enough to harm the eggs and dropping low enough to kill the fry or to drive the fish off their beds before spawning.
- e. The optimum temperature at which the carps spawn has been observed to be between 75 and 86°F (23.9 and 30.0°C).
- f. Silt-laden waters do not appear to be inimical to the spawning of carps and though the fertilized eggs sink to the bottom, the larvae hatch within 15 to 20 hours and come to the surface. Besides, in flowing waters, the eggs roll about and do not get covered with silt.
- g. In the spawning beds of the rivers there is practically no disturbance to the spawners.

- h. The migration of spawners to the shallow spawning beds exposes them to attack by enemies, including man, and it is desirable from the standpoint of fishery management that the brood fish should be protected during this period.
- i. For an increased production of fry, it is necessary that the spawning grounds should be improved artificially and that a sufficient area of proper material should be made available to the spawners.

From the above, it will appear that indigeneous fishes are adapted to the monsoon floods and other topographical, chemical and physical conditions encountered in the environment. In the Punjab, West Pakistan, the fishes did not breed during the years when rainfall is either untimely or insufficient to flood the grounds (Khan, 1942).

2. Possibilities of Artificial Propagation

As the important cultivated fishes of Pakistan spawn in the rivers, the fish farmer depends on the timely availability of the stocking material. (The term "stocking material" denotes the earliest developmental stages such as spawn, fry or fingerlings with which the entire culture operations are started.) Besides, much effort is necessary to collect, sort, condition and transport the stocking material to the fish farmers. If the fish could be induced to spawn in ponds or other confined waters by providing them

with optimum hydrological or ecological conditions, the procurement of the stocking material could be greatly simplified. Considerable success has been achieved in this respect with regard to common carp and gold fish. Catla, rohu, mrigal and kalbaus do become sexually mature in confined waters but do not spawn for want of essential stimuli. Cultivated species like salmon, trout and the Chinese carps can be stripped to obtain the eggs and milt, but this is not so with Pakistani carps.

The secretion of the pituitary gland of the fish has been found to induce ovulation and spawning. Clemens and Sneed (1962) observed that ripe females of most species of fish respond to pituitary injections by spawning within 12 to 20 hours, so that it is possible to predict rather accurately when a spawn will occur. This prediction allows the fish culturist to plan his work according to rigid schedule, since the injections, to some degree by-pass the variables in the environment, such as rain, flood, temperature and light. Since both males and females respond positively to pituitary injections, most species can be hand-stripped, a practice which offers additional advantages. Culture ponds can be stocked with eggs and fry of uniform size and age. Since the brood stock is not in the pond with the progeny, the possibility of transmission of disease from the brood stock to the offspring is minimized and the predation, if any, by the parent is eliminated. Hybrids

can also be produced whenever hybridization is desirable and feasible. Wild fish that have not yet been domesticated may be spawned more easily by the pituitary method. Frequently, more uniform spawning has been achieved by the injection of pituitary materials into ripe fish which, because of some environmental or physiological condition would fail to spawn without such treatment.

Russian (Gerbil'skii, 1941; Detlaf and Ginzburg, 1954) and Brazilian (de Menezes, 1954; Fontenele, 1955) fish workers have applied the pituitary method to the large-scale spawning of Acipenser sp. and Prochilodus spp. respectively. Today the Russians obtain all sturgeon eggs for culturing from pituitary-treated fish (Gerbil'skii, 1957).

Pickford and Atz (1957) and Atz and Pickford (1959) observed that (1) fish pituitaries contain hormones to precipitate spawning in ripe fish; (2) there is little, if any, specificity in the hormone of fishes, i.e., the pituitaries of one family or species are usually active in unrelated species (female Cyprinus carpio, however, responds to pituitaries only from the same species (Clemens and Sneed, 1962)); (3) there are a number of examples in which gonadotrophic materials from other vertebrates were found to be active in fish; (4) out of season spawning has been induced by the administration of gonadotropins; (5) fresh acetone dried, or frozen pituitaries as well as glycerin, salt and water extracts of pituitaries have similar activities; (6) under

most experimental conditions the injection of pituitaries does not decrease fertility; (7) increased or decreased exposure to light (depending on species involved) may have the same effect on sexual development and spawning as pituitary injections; (8) lack of response in some experiments with mammalian gonadotropins may be due to the fact that the dosage was too low; (9) there is little or no qualitative difference in the pituitaries of the male or female donor fish, at least from the practical point of view; and (10) there may be seasonal difference in the biological effect produced by pituitaries taken from fish prior to spawning and those taken immediately after spawning.

The need to induce the indigenous carps to breed in confined waters and thereby ensure a dependable source of quality fish is being greatly felt in Pakistan today. The first attempt in this work was made by Khan (1938) who tried to induce spawning in Cirrhina mrigala by injecting the anterior lobe of mammalian pituitary gland into the fish. Although ovulation took place, the treated fish did not spawn and the stripped eggs could not be fertilized. Since then no work has been done in this field in Pakistan. In India, however, Ramaswami and Sundarraaj (1956, 1957a, b) have become successful in inducing catfishes (Heteropneustes (Saccobranthus) fossilis and Clarias batrachus) to spawn by hormone injections. Alikunhi et al. (1960) injected intraperitoneally the alcohol preserved pituitary material of

Labeo rohita (sexes mixed) in three species of carps namely, Labeo rohita, L. calbasu and L. bata. The successful doses varied from 1.5 to 4.0 glands for L. rohita, 0.33 to 1.0 for L. bata and 0.5 for L. calbasu. Two injections, sometimes one, were enough to induce spawning within a period of 7-12 hours. Chaudhury and Alikunhi (1957) and Chaudhury (1960) reported successful spawning of Labeo rohita, Cirrhina mrigala, C. reba, and Barbus sarana by intraperitoneal pituitary injection. Partial success was achieved in the case of Catla catla and Labeo bata. Glands of Catla catla induced spawning in Cirrhina reba, Barbus sarana and Cirrhina mrigala, while glands of Labeo rohita induced successful spawning in Labeo rohita, Cirrhina reba and Barbus sarana and ovulation in Catla catla and Labeo bata.

The results of experiments of the Indian workers may be applied in Pakistan as the carps are similar in both the countries. If successful, this may, in due course, lead to the production of quality stocking material on a commercial scale.

However, it is a fact that fish farmers are not well-off and have no capital to invest, so stocking material must be made available to them as cheaply as possible. Some time will be required to develop skill and avenues of supply for stocking material from pituitary-treated species. Hence it is important to improve the spawning grounds and encouraging pond breeding to increase the supply and quality of stocking material.

The improvement of spawning grounds is the concern of inland fisheries department and requires extensive research while pond breeding is the concern of the fish culturists. It has been found experimentally (Hora, 1945a) that carps do spawn in special "bundhs" or large embanked ponds where riverine conditions are simulated. Further research in these lines is also needed.

E. Procurement of Stocking Materials

1. Collection and Hatching of Carp Eggs in East Pakistan

a. Collection.--The professional fishermen collect the fertilized eggs within 14 hours of the spawn from a 16 km. (10-mile) zig-zag course of River Halda in Chittagong extending from Napitarghat to Ramdas Munshirhat (Ahmad, 1948). As breeding grounds are situated very near the tidal zone, the eggs are collected shortly after spawning, otherwise they are destroyed by the tidal brackish-water.

The spawning occurs during the full moon in the months of April to July (Ahmad, 1948). There may be as many as four spawnings in one year. In the beginning of the season, the spawn collectors fix their nets at suitable spots in the river and examine them carefully. As soon as some eggs are spotted, the collection is intensified.

The collecting gear consists of a rectangular, 12 m. x 2.7 m. (39.4 ft. x 8.9 ft.) mosquito netting. It is

strengthened with ropes at the margins and ends are tied to two bamboo poles, each about 2.5 m. long. It is generally held from a boat by two men, one sitting at the bow and the other at the stern. The bamboo poles are fixed by means of wooden hooks to the sides of the boat. The net is lowered into the water in such a way that it remains behind the boat and does not get entangled. Some collectors stand knee to shoulder deep in the water with net. The eggs collect in a bag-like hollow of net formed by the force of the current. The net is hauled up when a sufficient quantity of eggs are obtained.

The collected eggs in various stages of development are transferred to the boat, a part of which is partitioned breadthwise with mud. Many eggs hatch here. Some loss of eggs takes place here due to congestion and lack of aeration.

b. Hatching.--The eggs are transferred to hatching pits locally called "hapas," dug along muddy banks of the river and its tributaries within 4-5 hours of collection. The average size of hapa is 5 m. x 2.5 m. x 0.5 m. (16.4 ft. x 8.2 ft. x 1.6 ft.). The hapas are arranged in one or two rows, the one adjacent to the river gets its water supply direct from it through bamboo pipes or hollow betel nut trunks and the other row is fed from the first. The water is drained from the hapas into the river. The hapas are covered by a mosquito netting with its marginal ropes being tied to the wooden pegs on the ground at short distances.

The net is allowed to sag about 15 cm. (0.5 ft.) below the surface of the water in the shape of a bag under which some strong bamboos are placed parallel to each other. These are frequently rolled with care in order to agitate the eggs to surface. Each hapa can accommodate 120 to 300 kg. of eggs numbering from 900,000 to 2.2 million. Taking 5 mm. as the average diameter of an egg, about 450,000 eggs can be spread in a single layer in a hapa. The eggs hatch within 6-24 hours depending upon the stage of development of the eggs when they are introduced into the hapa and pass through the meshes of the nets into the water below. The net contains membranes of hatched eggs, dead and decomposed eggs, dead and live insect larvae, shrimps, etc. These are removed along the net when all the larvae have hatched out. Carp larvae remain in the hapa for two days when they are collected with the help of close-woven sheets of cloth and transferred into another hapa containing fresh-water. This process is repeated for about a week.

The over-crowding of eggs in the mosquito netting and the consequent failure of many of them to hatch is one of the main reasons for low survival of eggs in the hapa. The provision of a rectangular tank-like structure made of net and the outer one of cloth has been suggested by Ahmad (1948). The corner of inner tank should be tied to the corresponding corners of the outer tank and the whole device is tied to bamboo poles. Thus as both the receptacles are

kept stretched, the eggs can be separated uniformly. The eggs should be introduced into the inner receptacle so that the hatched eggs passing through the meshes of the net into the cloth receptacle below can be removed easily. If a constant flow of water is maintained, there will be no need to transfer the larvae from one hapa to another as is now practiced. It is also suggested that instead of placing the eggs in the earthen enclosures in the boats where the water turns muddy and hampers the development of eggs, earthen vessels should be used.

2. Collection of Carp Spawn

The term "spawn" applies to laid eggs with some hatchlings associated with them, but traders loosely apply it to cover eggs ("dim"), yolked larvae ("dimpona"), and fry up to 8 cm. long ("dhanipona"). "Phuldhani" is the name of fine dhanipona.

Besides Chittagong, where only the eggs are collected carp fry are collected from the left bank of the Padma (or the Ganges) covering a distance of about 96 km. (60 miles) from Godagari Ghat to Sarda and small pockets of the Jamuna near Serajganj and the Padma near Raita. Generally speaking, the fry are collected from nearly all the rivers during the monsoon. The spawn collection centers are selected on the basis of the empirical knowledge of the fishermen. The collection centers may change from year to year according to

the then prevailing topographical conditions.

The collecting gear consists of a funnel-shaped net called "benchi jal." The spawn drifting down the river are caught within the wings and mouth of the net and led into a part of it called "gamcha" or rough cloth where they accumulate. Usually 15 to 25 nets are operated by a group of 7 to 12 persons.

The spawn are removed hourly from the gamcha with the help of small bowls and allowed to pass through a crude sieve to remove miscellaneous floating objects, debris, young shrimps, fry of catfishes, etc. The catch from one benchi jal averages about 35,000 larvae. The sieved spawn are placed in large earthen jars in the boat from which they are transferred to hapas for holding till distribution. Most of the spawn develop into fry in the hapa.

3. Breeding the Major Carps in Bundhs

Even though the eggs and fry of major carps are collected from rivers, some are also raised from specially constructed spawning ponds called bundhs. These are small reservoirs actually meant for collecting and storing rain water. They are built in natural depressions, valleys or low lying rice fields in which rain water accumulates. The low end of such a depression is surrounded on three sides by strong embankments. The bed of the reservoir is plain, a shallow corner of which forms the spawning ground called

moan. Some grass is grown on the moan to hold the soil and prevent the water from becoming muddy during collection of eggs. During the monsoon, rain water flows into the bundhs in streams locally called dhals. In chittagong, a mud wall is raised in the upland area to hold the water which later flows into the bundh through a slit made in the wall. An outlet is provided on the opposite side of the bundh to drain off the used water. The bundh is stocked with breeders of the major carps (Catla catla, Labeo rohita, Cirrhina mrigala and Labeo calbasu) in the proportion of one female to two males as soon as the monsoon is set. In a bundh with the embankment of about 350 m. length, having a spawning ground about 6,000 sq. meters in area, 200 catla, 100 rohu, 100 mrigal and 40 kalbaus are stocked. When the water level in the bundh increases and shallow spawning grounds are submerged, the brood fish gather there and start sex play. Maximum spawning takes place at night during the full moon.

The eggs are collected by using rectangular mosquito nets of 4 m. x 1.5 m. size. Many eggs are destroyed by the collectors trampling on them. The collected eggs are transferred to earthen jars or kerosene tins and then to the hatching pits or hapas. Rows of hapas, each having the size of 1.3 m. length, 0.6 m. width, and 0.3 m. depth are constructed in rice fields near the bundh. They are fed with the water overflowing the bundh through small canals. Six brass bowls of eggs are released into each hapa filled with

water. The inlet is then closed and the temperature of the water rises thus reducing the hatching time, and within 24 hours the hatching operations are completed. Many eggs die in the stagnant waters of the hapa from bacterial action and lack of sufficient aeration. The larvae are sold to nursery men and those left over are reared by the bundh owner in fry ponds.

4. Identification of Fry

The carp fry are collected along with those of various undesirable species. Pond owners and fry collectors cannot differentiate between the fry of different carps below a size of 3 cm. Mookerjee et al. (1944) and Alikunhi (1956) attempted to prepare a key to their identification (Table 15).

F. Transport of Fish Fry

1. Existing Methods and Their Improvements

Live fish fry are transported from the spawning sites to the nursing, rearing and stocking ponds which are situated throughout East Pakistan, and in the Punjab and Sind of West Pakistan (Figure 2).

The fry are transferred by dipnet or by bucket into earthen jars ("hundies"), each having a capacity of nearly 40 liters. A hundy contains about 60,000 larvae or fry 4-5 mm. in length. Generally, 75-100 g. of colloidal red soil is stirred into each jar (this is, however, not practiced in

TABLE 15. Salient characters of fry and fingerling of major carps^a

I. Head conspicuously large from 11.2 mm. stage and broad from 17.8 mm. stage. No barbels. Reddish color of gills visible through transparent opercular flaps <u>Catla catla</u>	
II. Head of normal size and shape.	
A. Three to four black spots on caudal peduncle enclosing a white space. Lips fringed, color generally grayish; a yellow spot at the anterior base of dorsal fin and a yellowish band at the base. Barbels black <u>Labeo calbasu</u>	
B. Spots on caudal peduncle not enclosing a white area.	
1. Lips fringed.	
a. Body marked with longitudinal bands, with fine black dots <u>Labeo gonius</u>	
b. Body without longitudinal bands, fins marked with vermillion red <u>Labeo rohita</u>	
2. Lips entire.	
a. Black spot on either side of body on the 5th and 6th scales of the row above lateral line <u>Labeo bata</u>	
b. Black spot absent.	
1) A black blotch at base of dorsal fin present <u>Barbus chola</u>	
2) Black blotch at base of dorsal fin absent.	
a) A short, slanting vertical band later becoming an oval or round spot below anterior end of dorsal fin <u>Barbus sarana</u>	
c. Band or spot below anterior end of dorsal fin absent.	
1) Margin of lips black; minute black dots along lateral line at 11.5 mm. stage, later forming a longitudinal band <u>Cirrhina reba</u>	
2) Margin of lips rather whitish; body marked with several longitudinal black bands <u>Cirrhina mrigala</u>	

^aSources: Mookerjee et al. (1944); Alikunhi (1956).

Chittagong, East Pakistan). The jars are carried to the nearest railroad station, slung on bamboo poles. During transport, the water in the jars is kept in constant agitation by the fishermen. This facilitates the elimination of accumulated CO_2 and absorption of O_2 . Water is also changed from time to time. They may be transported to a distance of 100 miles or more for sale.

The red soil used by the fry traders has a pH of about 8.5. Basu (1951) showed experimentally that this red clay helps in collecting dead larvae at the bottom. It is colloidal in nature and possesses a positive charge so that negatively charged dead and floating larvae attract the clay, become heavy and sink to the bottom and are removed. The dead ones get buried under the soil that settles over them and organic pollution in the jars is thus localized to the bottom sludge. Saha and Chaudhury (1956), however, observed that this soil has no especial effect on the life of the fry; any ordinary soil in finely pulverized condition is as effective as the red soil in increasing the survival period of the fry.

Even though the jars are comparatively cheap and help in keeping the water cool during transport, their disadvantage is that they are brittle. When fry transport is intended commercially over long distances earthen jars are very inconvenient to handle.

In order to prevent breakage of jars in transit and to change the water easily, fish transport cans (0.5 m. diameter at base and 38 cm. in height), as are used in Germany (Schäperclaus, 1933), may be tried in Pakistan. The can is fixed on a wooden base which avoids heating through contact with warm surfaces during transport. A close-fitting moist woolen jacket helps to maintain a uniform cool temperature during transport even when the can is exposed to the sun. Its mouth is about 20 cm. wide and has a pressed-in perforated lid to admit air and at the same time prevents the splashing of water or the fish from jumping out. Fifty to hundred fry can be transported in this type of tin can. See also Krause (1957), and Fry and Norris (1962) for further details regarding the transport of fish in open containers.

When transporting the fry by air, open containers cannot be used. Hermetically sealed containers like airtight tins used in transporting kerosene and gasoline with excess of O_2 may be used (Vaas, 1952). These containers have wide mouths with a tightly fitting screw stopper and washer. They have two metal pipes or rubber tubes, reaching the bottom, one with a narrow bore so that O_2 can bubble through it. First, the container is filled to more than two-thirds with clean, filtered pond water. Then the fry are introduced through the mouth and the container is filled with water completely to exclude all air. The mouth of the container is now closed and the O_2 is introduced through the narrow pipe

from the oxygen cylinder through a regulator. Since the can is filled with water, a volume of water equal to the volume of oxygen introduced will be displaced through the second pipe. By measuring this volume, it can be ascertained whether the required quantity of oxygen has been introduced. When sufficient oxygen has been introduced, both the pipes are hermetically sealed (Vaas, 1952).

Plastic-bag transport (Miller, 1956) of live fish first came into general use less than a decade ago. The usual method of using plastic bags for shipping is to place two bags, one inside the other, in a cardboard box. This box is often insulated with slabs of glass wool or expanded cardboard. The desired amount of water, usually 5 gallons or less, is poured into the inner bag. The fish are introduced and the bag is partially inflated with oxygen and sealed with rubber bands. The box is then sealed and shipped to its destination by air. The primary advantages of the method are reduction in shipping weight and reduction of injury resulting from fish hitting container walls (Fry and Norris, 1962).

In closed containers CO_2 will necessarily build up in the water. Acid pH caused by CO_2 may be counteracted by tris (hydroxymethyl) aminomethane, an organic buffer, which showed a 50-fold increase in buffering capacity at 20 g. per gallon with maximum hydrogen ion absorption between a pH of 7.5 and 8.5 (McFarland and Norris, 1958). Inorganic buffers

like boric acid, sodium monophosphate, sodium biphosphate and sodium bicarbonate have been tested with conflicting results (Vaas, 1952; Srinivasan et al., 1956).

Ammonia will largely be neutralized by the respiratory CO_2 . See also Alabaster and Herbert (1954).

The problems which must be met in the successful transportation of live fish fry are many and diverse. The primary problem arises from the low capacity of water for oxygen together with its low capability to dissipate the end products of metabolism. The second problem is that of handling. In delicate species, abrasion needs only to be sufficient to remove the mucus from a fraction of the area of the skin in order to rob them of essential protection from osmotic stress. Many fish, too, are so stimulated by handling that they readily accumulate dangerous levels of lactic acid in their blood (Black, 1958). Excessive changes in temperature are also deleterious, as is well known. For a recent review on these crucial factors see Norris et al. (1960).

The optimum number or weight of different species of fry or larvae that can be transported in a container, open or closed, depends upon the species (rate of respiration), fish size, general physiological and health condition of the fish, the water temperature in the transporting vessel, and the duration of the transport (Krause, 1957). Hora and Pillay (1962) write that tins of 18 liter capacity are used

in India to transport the fry of major carps in presence of 6 liters of free oxygen. In such tins, 900 to 1,000 fry of 1-2 cm. length or about 285 g. of fry of that length can safely be transported by air for over 20 hours. They (1962) have quoted the following figures (Table 16) from the Hong Kong Fisheries Research Station regarding the transport of such Chinese carps as grass carp (Ctenopharyngodon idellus), big head (Aristichthys nobilis), silver carp (Hypophthalmichthys molitrix), and common carp (Cyprinus carpio). These data may be useful as a guide in fry transport in Pakistan.

2. Physiological Requirements

Respiration--The Level

The level of oxygen required is something more than the bare minimum that will prevent asphyxia in an undisturbed fish. Fish must at least perform compensatory movements throughout the journey. Furthermore, fish are easily stimulated to increase their oxygen consumption to near their maximum rates, and are slow to return to the resting level, so that the excitement of capture and transfer to the transporting containers is likely to increase greatly the need for oxygen. There is also the possibility that an initial severe struggle may lessen the ability of the blood to transport oxygen for some time afterward. A suitable physiological standard for the oxygen consumption of fish fry in transport

TABLE 16. Number of Chinese carp fry that can be transported in a container of 18.5 liter capacity containing 8.5 liters of free oxygen^a

Size of fry (mm)	Weight per 1,000 fry (g)	Number of fry	Amount of free oxygen per g. of fry (ml)
10-20	50-200	4,000-5,000	42.5
30	450	1,500-2,000	12.9
40	800	800-2,000	10.6
50	1,500	500- 800	5.7
60	2,500	400- 500	3.4
70	3,000	350- 400	2.8
80	3,500	250- 300	2.4
90	4,500	200	1.9
100	6,000	150	1.4
110	8,000	100	0.85
120	12,000	80	0.70

^aSource: Hora and Pillay (1962).

is 50% more than they require strictly for maintenance in an undisturbed state (Fry, 1957).

Large individuals consume less oxygen per unit weight than do the small ones, as is well known. The consumption of oxygen rises with temperature up to an optimum level but is relatively independent of size (Job, 1955). The metabolic rate rises proportionately up to an optimum temperature (29°C in case of milkfish) and then falls (Job, 1957). The relative increase in rate of oxygen consumption is greatest in fish fry. Saha et al. (1956a) found that the fry of major carps cannot live in oxygen concentration below 0.5 p.p.m. Fry which are 4-8 cm. long can stand oxygen concentration up to 25 p.p.m. in the water for over 24 hours.

For every milliliter of oxygen that a fish consumes, it will produce approximately 0.9 ml. of carbon dioxide. The fate of this gas will be to enter into the equilibrium system of carbonates, bicarbonates and free carbon dioxide dissolved in the water. From the point of view of respiration, only the fraction that accumulates as free carbon dioxide needs to be considered. The effect of increase in free carbon dioxide is to depress the ability to take up oxygen (Basu, 1959). When oxygen concentration was 2 p.p.m. or more, carbon dioxide was found lethal for the fry of major carps at 250 p.p.m. (Saha et al., 1956a).

Accumulation of Ammonia

Nearly 50% of the nitrogenous excretion of fish is ammonia which, in non-ionic free form, is a toxic substance (Duodoroff and Katz, 1950). Saha et al. (1956b), however, have found that the fry of major carps can tolerate 20 p.p.m. of dissolved free ammonia and 15 p.p.m. of ammonia in the form of inorganic salts.

3. Conditioning

Fry that are transported immediately after collection have low survival rate as they are suddenly kept congested in containers where they vomit the food eaten before capture or pass excreta which aggravates the oxygen demand. To avoid this, fish farmers in East Pakistan condition the fry by keeping them in small nursery ponds for 12-24 hours after collection. Here they clean themselves and get accustomed to living in limited space with comparatively less oxygen (Ahmad, 1957a).

G. Nursing and Rearing Carp Spawn

1. Principles

In East Pakistan, ponds, lakes, and reservoirs are used for stocking. Before considering pond culture or stocking operations (see page 113), it will not be out of place to consider nursing and rearing the carp spawn near the collection site before, or the stocking sites after, transport.

Although a stocking pond is much safer for the young fish than the natural waters, it is not recommended that they should be released there right after collection or transport. Their food and feeding habits are, in many cases, different from those of the adults. Little care can possibly be given to the young fish if they are released in the stocking ponds where associations of different size-groups or species are raised. They will be exposed to predation and their numbers greatly reduced. In view of these considerations, it is important to rear the young up to the fingerling stage in separate nursing and rearing ponds before transferring them to the stocking ponds.

Nursing ponds should be less than one-third of an acre in size, while the rearing ponds may be larger than that. The small size of nursing and rearing ponds facilitates efficient control of ecological conditions such as the quality and quantity of water, condition of soil, predation, etc. These ponds should be less than three feet in depth, as the fry need warm waters for rapid growth. Besides, shallow waters promote growth of their food such as blue-green algae and diatoms.

Other advantages of shallow nursing and rearing ponds are as follows: (a) they are easily drainable; (b) they dry up during later winter months and their bottom muds are aerated and mineralized, production of H_2S is interrupted and oxidation of organic matter initiated; (c) the fish

enemies living in the ponds can be controlled; (d) application of poisons to control predators resistant to drying or of manures to increase their productivity is easier; (e) cultivation of leguminous plants to increase productivity of the bottom soil by fixing atmospheric nitrogen is possible; (f) harvesting of fry will be easy; and (g) large stocks of fry can be raised in close proximity to the areas selected for fish farming (Hora, 1945b).

2. Procedures

- a. The seasonal ponds to be used as nurseries should first of all be drained to dryness.
- b. The thoroughly dried bottom of the pond should be ploughed well and short-season crops like legumes grown to increase productivity of the bottom. It should again be ploughed and leveled when the crop is harvested. If the pond soil is acidic, liming should be done so as to bring the pH up to 8.5.
- c. Manuring of nursery ponds may be done with cow-dung at the rate of 250 kg. (550 pounds) per hectare.
- d. Ponds are filled with rain or any clean water from a nearby source.
- e. Eradication of predators is possible in a drainable pond. If a perennial pond is used as a nursery, predatory fishes and insects may be eradicated by applying rotenone evenly at the rate of 4-6 p.p.m. on a quiet day. The

dead or stunned predators should be removed from the pond and destroyed. Measures such as spraying of an emulsion of 56 kg. of mustard oil and 19 kg. of washing soap per hectare of pond surface will remove predatory insects (Hora, 1945b). Access of external predators to the nursing ponds may be checked by fencing the embankments.

- f. At least three million fry can be reared to fingerlings in 15 days in a nursery pond having an area of 0.5 hectare. The plankton produced by manuring with cow-dung are generally zooplankters which are excellent food for the carp fry. If there is any chance of pollution, the plankton may be raised in small ditches and transferred to the nursing pond. In case of waterbloom, duckweeds (Lemna sp.) may be released in these ponds which will cut off light penetration and the bloom will die out.
- g. If the natural food is insufficient in a nursery, repeated transplantations and artificial food will enhance their growth. Fry fed on oil cakes at the rate of one to three times the weight of the fry at the time of releasing into the nursery grow rapidly. Hora and Pillay (1962) suggested the following feeding schedule:
 - 1) First five days after stocking:
Artificial food equal in weight to that of the fry stocked.

- 2) Second period of five days after stocking:
Twice the weight of fry at the time of stocking.
- 3) Third period of five days after stocking:
Three times the weight of fry at the time of stocking.

A fry about 6 mm. long weighs nearly 0.0014 g. and a bowl 7.6 cm. in diameter and 3.2 cm. in width holds about 30,000 fry of the said length. For each bowl of fry, 4 bowls of rice bran, 3 bowls of mustard oil cake, and 2.5 bowls of peanut oil cake are the estimated feed.

- h. After 15 days the fry which are now about 35 mm. long should be removed to rearing ponds. The fry collecting net may have a mesh size of 13 mm. A nursery pond can be used to rear successive lots of fry.

The preparation and management of rearing ponds are similar to those of the nursing ponds. Fry of about 35 mm. length should be stocked in rearing ponds at the rate of 250,000 to 500,000 per hectare of pond area. When they grow up to fingerling stage (130-155 mm.), they are safe for transfer to stocking ponds.

H. Fish Culture in Freshwater Ponds

Fish culture in Pakistan can be divided into the following categories:

- a. Fish culture in fresh-water ponds
- b. Fish culture in lakes, reservoirs, swamps and irrigation canals

- c. Fish in rice fields
- d. Fish culture in brackish-water swamps and rice fields.

These will now be considered separately.

1. The Pond

a. Definition

A pond is a body of water having slight depth occupying a basin and lacking continuity with the sea (Forel, 1892). It does not stratify thermally (Muttkowski, 1918). It is a quiet body of water in which the littoral zone of floating-leaved vegetation may extend to the middle of the basin and in which the biota is very similar to that of the littoral zone of lakes (Welch, 1952).

In pond industry, the fish pond always signifies a drainable flat body of water (Schäperclaus, 1933). Pond culture is profitable only under favorable fishing conditions, i.e., where drainage of ponds or fishing with nets is possible. Non-drainable ponds with the exception of drinking water ponds and village ponds are less productive than the drainable ones.

Thus the ponds are: (1) non-drainable, (2) drainable or true fish ponds. In respect of water supply, ponds are: (1) spring water ponds (mostly in West Pakistan); (2) rain water ponds (in East Pakistan); (3) brook ponds such as feeder ponds; or (4) river ponds.

According to origin, ponds are those (1) which represent the pond stage in the extinction of previously existing lakes; (2) which have not been preceded by a lake; and (3) those which are the results of man's activities (excavations, quarries, etc.). It is the third category of ponds on which the following discussion will largely be based.

b. Fish Ponds of East Pakistan

Fresh-water ponds are a distinct element in the village economy of this province. In addition to innumerable water-filled ditches, this province has 264,355 ponds (Table 17), 150,000 of which are regularly stocked with fish (Ahmad, 1957c).

Village ponds are used for bathing, washing, and watering livestock. They are the communal property of the village. Homestead ponds are more numerous in the southern districts of the province (Figure 7). Here borrow-pits have to be dug in almost every home for construction of houses and reclamation of low-lying areas. Homestead ponds are used for the supply of drinking water as well as fish culture.

Little attention is being given to the upkeep of these ponds. They may be overgrown with vegetation except at the spots used for domestic purposes, and form permanent breeding areas for mosquitoes.

TABLE 17. Distribution of ponds in East Pakistan^a

Name of Districts	Number of ponds
Noakhali	43,747
Faridpur	38,517
Mymensingh	26,845
Comilla	26,230
Dacca	19,394
Khulna	17,649
Bogra	16,988
Rajshahi	16,179
Dinajpur	15,109
Jessore	14,274
Barisal	7,288
Chittagong	6,985
Rangpur	5,016
Sylhet	4,699
Kushtia	3,330
Pubna	1,805
Chittagong Hill Tracts	<u>200</u>
Total	264,355
Area of East Pakistan	54,501 sq. mi. (14.1 mill. ha.)
Area of ponds	75,000 ha.
% of area of ponds to total area of the province	0.5

^aSource: Ahmad (1957c).

c. Improvement of Existing Ponds

To increase the production of fish in ponds, the immediate need is to improve the present ones rather than constructing expensive new ones. In order to improve these ponds, it is essential to:

- 1) Control growth of aquatic plants in such a way as to discourage quick regrowth. Measures of their control will be dealt with on page 146.
- 2) Drain and desilt them. Draining will be easy when ponds are situated in areas where the water can be drained off into other low-lying areas. Otherwise expensive mechanical devices will be required. The silt removed from the pond can be used to repair embankments, or it may be used in gardens and agricultural lands. If it cannot be drained because of depth or restricted water supply, some of the excessive organic deposits may be removed by using flat bamboo shovels fitted with long handles in order to reach the pond bottom. The deposit is collected and placed in boats or thrown to the banks.
- 3) Remove the predators by repeated fishing or by suitable poison.
- 4) Raise and strengthen the embankments, wherever necessary.
- 5) Provide each pond with an inlet and an outlet. These may be of wood because concrete and galvanized iron

pipes will be costly. The inlet and outlet should be provided with fine-meshed sieves to prevent the extraneous and predatory fish from entering the pond and stopping the escape of those being cultured in it.

d. Construction of Fishponds

Ponds meant for fish culture need special construction. It is the most expensive part of the whole enterprise and success or failure of it depends, to a large extent, on the suitability of the pond constructed. Pond construction is an engineering problem. Insufficient training in this field is likely to lead to the selection of unsuitable site, and faulty construction, resulting in the loss of money and effort. Topography of the area, nature of soil, water supply, etc. should be considered in detail before the actual construction work is started.

Selection of site.--When making a choice for the location of a pond, it is necessary to consider that a location upon a muddy or clayey soil is profitable because such soil is otherwise unusable. If a pond is at all constructed on a potential agricultural land, it does not necessarily compete with its agricultural use as it is also used for other purposes like growing water chestnut and water lily for human consumption and sometimes water hyacinth for cattle. Duck raising is also carried on concurrently (Hickling, 1948).

Low-lying areas of the districts of Noakhali, Faridpur, Mymensingh, Comilla, Dacca, Barisal, Khulna and Sylhet are ideal for pond construction (Figure 7). Easy approachability is an important factor in site selection. In deltaic regions, and areas adjoining rivers, canals and lakes, water transport will be possible and this will reduce the cost of the supply of stocking material as well as marketing the produce.

The problem of water-logging which is looming large in part of West Pakistan can be solved to some extent by fish culture. For this purpose, the water pumped out of the boggy land may be collected in ponds dug-out at the lowest level of the land, water weeds and hydrophytes planted therein and fish introduced. The returns from the sale of fish will meet to a great extent the cost of pumping and digging the ponds. The water will be free of salts after some time as the vegetation will absorb the salts. Euryhaline fishes like Tilapia, will be ideal for culture in such waters.

Water supply.--Although ponds are fed with rain water, it is desirable to have them constructed in areas where running water is always available because draught or untimely rainfall may be a hindrance to fish culture. For all types of ponds, the availability of water from river, canal, tube well, artesian well or spring is desirable. Hickling (1962) has shown that, for a pond of one acre, three feet deep, about 816,750 gallons of water will be

Figure 7. Map of East Pakistan showing the districts,
the Sundarbans and the major fresh-water
rivers.

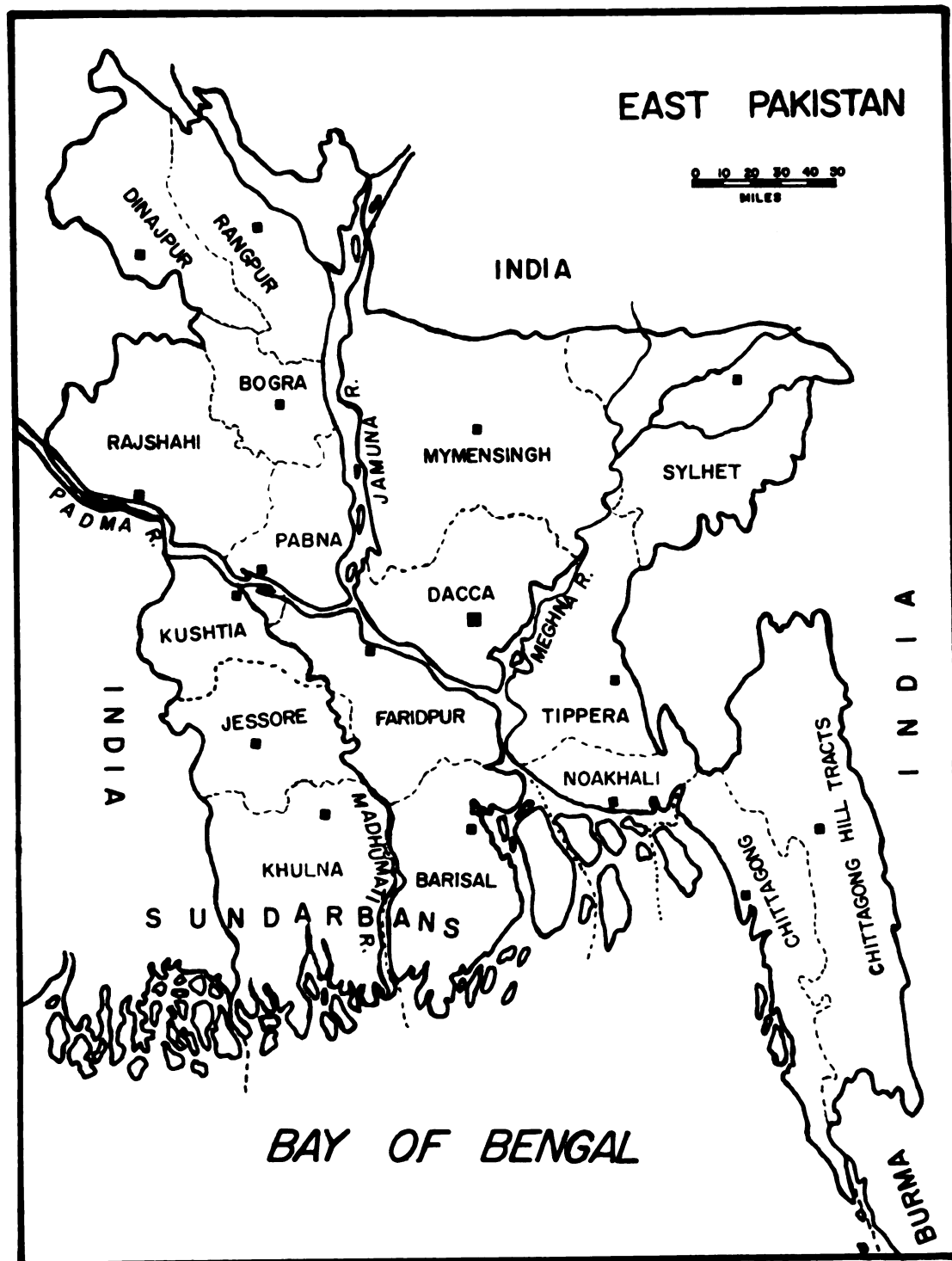


Figure 7

needed to fill, and, assuming a rate of loss through seepage and evaporation of half-inch per day or three and a half inches per week, about 80,000 gallons per week are needed to keep it filled. This is a moderate amount of water, equivalent to three and a half hours' inflow at one cubic foot per second. The site should be free from flooding and surface drainage, as these might cause washout of the dykes resulting in loss of fish.

Size and shape.--The usual size of a pond is one-third to three acres. It may be of any shape, but a rectangular pond is desirable, as it will facilitate the removal of fish by nets operated from one end of the pond to the other. The depth of a fish pond ranges from 1-2.5 m.

The pond site should first of all be cleared of all trees, brush, etc. The top soil is collected and kept aside for use as fertilizer. The surface soil is kept for fencing the embankments on which grass and other vegetation are grown. The shape of the embankment depends on the type of soil, but generally a slope of 3:1 is considered adequate (Hora and Pillay, 1962).

Inlet and outlet arrangements.--The inlet is provided near the source of water supply and outlet at the deepest portion of the pond. The inlet should be guarded against the entrance of undesirable fishes by means of fine-meshed screens. Hollow palm or betelnut stem is generally used as inlet pipe.

Prevention of seepage.--Newly constructed ponds do not usually hold sufficient water if they are situated on gravelly or sandy soil. The bottom of such ponds should be covered with a layer of mud or clay at least 20 cm. thick before they are filled. This will reduce considerably the loss of water due to seepage.

Other arrangements.--The whole fish pond should have a good fencing to prevent the entry of cattle, etc. A few shade trees may be grown near some portions of the pond to give shade where the fish may protect themselves from the heat of the summer sun. In shallow ponds, marginal and central ditches may be dug where the fish may retreat during hot days.

2. The Water

Two fundamentally different requirements confront the fish culturist with regard to the physical and chemical conditions of water which is the basic element in fish culture. They are: (1) The water must offer the fish (as well as other biologically productive organisms) near optimum physical conditions of existence. (2) The water must contain the nutrients needed for primary production in optimal amounts, or they must be regularly renewed from outside or must be replenished through the process of decomposition within the pond.

These two requirements are physico-chemical in nature and overlap each other.

a. Physical Properties of Pond Water

Shallowness.--The relatively high productivity of the pond is, to a large extent, due to its shallowness which allows the penetration of light to its very bottom, and at the same time facilitates the rapid warming process of the water mass. The strata below two meters add little biological production in tropical regions. However, ponds shallower than one meter may develop temperatures high enough to affect productivity adversely and may lead to loss of fish.

In a shallow pond, soil and water have greater surface of contact per unit of volume than a deep pond, so that more nutritional matter from the soil is dissolved which usually means greater productivity.

Light.--The shallow depths of ponds usually make possible an illumination of the entire bottom by effective light so that plants may occupy the entire basin. Luxuriant growth of plants produce, of course, much shading of the underlying waters. Unshaded ponds with clear water may be illuminated through with an intensity almost as great as that of the surface. Light penetration is much affected by the irregular and sometimes abrupt variation in turbidity. Since the shallowness allows such complete illumination it follows that ponds, in general, are subject to the range of the daily seasonal variations in light supply.

Solar heat.-- Solar heat keeps the surface temperature of ponds constantly high thereby creating a stratification in them. Three distinct water layers are recognized:

(1) the epilimnion or the warmer waters of the surface zone, (2) the thermocline, a thin middle layer where the temperature drops abruptly, and (3) the hypolimnion, or the cooler water at the bottom. This thermal stratification may not be prominent in shallow ponds. It is generally believed that the surface layer of water in tropical climates does not mix completely with the layer below three meters except in ponds exposed to strong wind action. Instead of an annual turn-over, as found in temperate climates, a daily turn-over takes place in tropical ponds at night bringing about a mixing of the water. This turn-over is of extreme importance in the circulation of oxygen and nutrients in pond water (Hora and Pillay, 1962).

Temperature.--The temperature of water is obviously very important. All activities of poikilothermous creatures slow down as the temperature falls. Carp stops feeding at 10°C and becomes torpid at about 5°C (Hickling, 1962). Probst (1950) has shown that the yield of carp ponds is positively correlated with average temperature during the growing period (May to September). In Pakistan, there is little seasonal variation in temperature which is also high (Table 3), fish growth may proceed the year round, so that it is possible for fish ponds to show very high productivity. Because of shallow depth and large expanse of surface as compared with the volume, pond waters, in general, tend to follow the temperature of the atmosphere. A rise in

temperature causes downward migration of surface biota. High temperatures decrease the dissolved oxygen content of the water, increases oxygen consumption of the biota and the mineralization of organic matter. The temperature tolerance of various fishes cultured in Pakistan has so far not been explored.

Turbidity.--Turbidity, due either to plankton growths or to non-living suspended matter, varies greatly with the circumstances of season, productivity, nature of the basin, degree of exposure, rains, floods, inflowing sediments and other similar features. In turbid water, the photosynthetic rate will be reduced and the fish fauna needing clear, oxygen-rich water will be replaced by a predominantly labyrinthiform fauna. The turbidity tolerance of various cultivated species of fish is not yet known, although catfishes have been found well-suited for turbid waters.

Water movement.--Owing to the small area involved, water movements in ponds are minimal. Even in the most exposed ponds, wave action is very slight. Luxuriant plant growth, often accompanying features of ponds, further restricts water movements. Water movement or a current of water is necessary for the breeding of carps, although most of Pakistan's cultivated fishes can grow and fatten in lentic environments.

b. Chemical Properties of Pond Water

The existence and nutrition of the biologically active organisms in the pond depend upon the basic chemical elements, ten of which are of great importance: oxygen, hydrogen, carbon, nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, iron, and of minor importance are: sodium, chlorine, fluorine, silicon, manganese, iodine and arsenic. Most of these substances are found dissolved in the water in sufficient quantities through contact of the water with the soil and the air. Undissolved supplies come into the pond through inflow during rains and floods. The above-mentioned substances are present in the water in combined forms. They may be poisonous in free forms. They must be present in usable and combined forms since the quality of the water depends on the nature of their available combinations.

Dissolved oxygen.--Dissolved oxygen is important for the respiration of fish and other living organisms in the pond, with the exception of some anaerobic bacteria. It is obtained from the atmosphere, and the aquatic plant photosynthesis.

The oxygen carrying capacity of the water varies with its temperature and an increase in temperature results in a decrease in oxygen solubility. The figures in Table 18 show the normals (Schäperclaus, 1933).

TABLE 18. Temperature and dissolved oxygen relationship in pond water^a

Temperature (°C)	Oxygen (mg/liter or p.p.m.)
0	14.57
5	12.74
10	11.25
15	10.07
20	9.10
25	8.27
30	7.25

^aSource: Schäperclaus (1933).

While the dissolved oxygen content decreases with the increase in temperature, the oxygen consumption of fish increases with the increase in temperature. Absence of aquatic plants and putrefaction of organic matter cause diminution to depletion of dissolved oxygen. Wunder (1949) states that a dangerous oxygen deficiency may be caused in fish ponds as a result of fertilization. A very rich algal flora may develop which yields a high oxygen content to the water during the day, but at night the respiration of algae may reduce it to dangerously low levels.

There is a diurnal variation in the dissolved oxygen content of a pond; its quantity is least at dawn. Buschkiel (1937) shows that deoxygenation at night may be naturally prevented even where the pond is treated with large quantities of organic manures. The oxygen bubbles present in the algae at daytime dissolve at night helping to keep the fish alive until oxygen production begins again at dawn.

The rate of oxygen consumption of various cultivated species of fish in their different ages is not yet determined. It is estimated that a concentration of 5 p.p.m. at 20°C or over is sufficient to keep the fish healthy, supersaturation of oxygen has little ill-effect on fish (Hora and Pillay, 1962).

Biochemical oxygen demand (B.O.D.).--Biochemical oxygen demand is the amount of oxygen used up during the oxidation of three classes of materials: (1) carbonaceous

organic material usable as source of food by aerobic organisms; (2) oxidizable nitrogen derived from nitrite, ammonia, and organic nitrogen compounds which serve as food for specific bacteria (e.g., Nitrosomonas and Nitrobacter); and (3) certain chemical reducing compounds (ferrous iron, sulfite, and sulfide) which will react with molecularly dissolved oxygen. In raw and settled domestic sewage, most--and for practical purposes, all--of the oxygen demand is due to the first class of materials, while, in biologically treated effluents a considerable proportion of the oxygen may be due to oxidation of Class (2) compounds. The oxygen demand for Class (1) and (2) materials can be determined by a standard B.O.D. test but for Class (3) materials similar B.O.D. test may not be conducted unless it is based upon a calculated initial dissolved oxygen (American Public Health Association, 1962). It should be borne in mind that all three of these classes will have a direct bearing upon the oxygen balance of the receiving water and must be considered in the discharge of waste in such a water, because a rise in oxygen demand may mean depletion of oxygen and consequent death of fish.

pH rate.--The natural reaction of any liquid, including pond water, may be either alkaline (pH greater than 7.0), acidic (pH less than 7.0) or neutral (pH equivalent to 7.0). A good pond water has a pH rate of from 7 to 8 which means a feeble alkaline reaction. Dissolved calcium bicarbonate is

mainly responsible for the maintenance of such an optimal range of pH. A good pond water having adequate acid combining capacity will not show a pH range higher than 6.5 to 9.0 (Schäperclaus, 1933; Swingle, 1957). Swingle states that waters more alkaline than 9.5 are unproductive because carbon dioxide becomes unavailable in such alkaline water--the alkaline death point of fish being about 11.0.

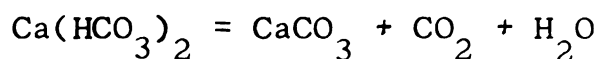
Many fish can tolerate wide ranges of pH. Swamp fishes like the snakeheads (Ophicephalus spp.) and some catfishes are known to live well in waters having a pH range of 4 to 9.

Acid water may diminish the appetite of fish and so reduce the rate of their growth. Acid water is less productive because there is a lack of carbon dioxide for photosynthesis. Alikunhi (1957) confirms that in India water on acid soil is generally less productive of fish than that on alkaline soil. In Madras State, India, waters of pH 6.5 to 7.5 gave an average yield of 200-500 pounds per acre, whereas, that of a pH 7.5 to 8.5 gave 1,000-2,000 pounds without feeding.

Generally a pH lower than 5.0 is considered unsuitable for fish life. Water with a pH of 4.0 cannot be used for fish culture. Those of pH 4.5 to 6.5 can be improved by sufficient liming to bring up the pH to about 8.0 (Schäperclaus, 1933).

Alkalinity reserve or bicarbonate buffering system.--

Alkalinity reserve is also known as acid combining capacity or titration alkalinity. It can be expressed as the calcium content of the water. It controls the extreme variation of pH. The process is like this: at an alkaline reserve of 7 c.c. N HCl per liter which corresponds to 196 mg. of CaO per liter (p.p.m.) the water contains 308 mg. per liter of calcium bicarbonate which again corresponds to 101.0 mg. of free CO₂ per liter. This will correspond to pH 7.0. If, due to photosynthesis, it loses 1 mg. of free CO₂, the pH will rise due to loss of acid properties. A part of calcium bicarbonate dissolved in the water will break down into calcium carbonate and free CO₂ until a free equilibrium and a corresponding pH is brought about. Calcium carbonate is deposited on the plants, or settled at the pond bottom. Conversely, when the water contains free CO₂ higher than 101.0 mg. per liter and the pH is consequently low (acidic), the excess of CO₂ dissolves the CaCO₃ deposited on the pond bottom into calcium bicarbonate (Ca(HCO₃)₂). The alkalinity reserve increases bringing up the pH and establishing the necessary equilibrium. This is a reversible process which can be expressed in the following equation:



This process takes place in the pond continuously and accounts for the fluctuation in pH.

Schäperclaus (1933) gives a table (Table 19) in which the alkalinity of the water, as measured by a simple and easy titration of the water, is correlated with its potential productivity of fish.

According to Schäperclaus, the most productive water is that which titrates 2-5 c.c. Hey (1947) observed that values between:

0-0.15 c.c. N HCl/liter--too acid to be of any value
for fish culture

0.15-2.0 c.c. N HCl/liter--usable but acid

3.5 c.c. N HCl/liter--optimum.

Free CO₂.--Water contains free carbon dioxide either from the atmosphere, or from the decomposition of organic matter and as a result of respiration of aquatic organisms. Accumulation of free CO₂ takes place generally at night.

High CO₂ content prevents oxygenation of water and may also adversely affect the extraction of dissolved oxygen from it by animals. Generally, 5 c.c. of CO₂ per liter is the upper limit for healthy growth of fish (Hora and Pillay, 1962).

CO₂ Tension.--Carbon dioxide tension is equal to the pressure or tension of CO₂ in the air above after the equilibrium has been reached in the water. It is not a measure of the total CO₂ present in the water but is a measure of its availability for photosynthetic purposes (Swingle, 1947). The actual amount of CO₂ present as free CO₂ and as

TABLE 19. Alkalinity and pond cultural significance^a

Alkalinity expressed as c.c. N/10 HCl required to neutralize 100 c.c. pond- water	Pond cultural significance
Zero or negative	Water strongly acidic, unus- able for fish culture, liming unprofitable in most cases.
0.1-0.5 c.c., equivalent to 2-8 drops of N/10 HCl	Alkalinity very low. Danger of fish dying, pH variable, CO ₂ supply poor, water not very productive.
0.5-2.0 c.c., equivalent to 8-30 drops of N/10 HCl	pH variable, CO ₂ supply medium, productivity medium.
2.0-5.0 c.c., equivalent to 30-75 drops of N/10 HCl	pH varies only between narrow limits, CO ₂ supply and productivity optimal.
5.0 c.c., equivalent to 75 drops of N/10 HCl	Rarely found, pH very con- stant, productivity alleged to decline but not proven so far. Health of fish not en- dangered.

^aSource: Schäperclaus (1933).

bicarbonate CO_2 at any given CO_2 tension varies depending upon the concentration of salts and kind of salts in solution and the temperature of the solution.

The CO_2 tension of the fish's blood and that of the water in which it lives both exert a powerful influence upon respiration. A high CO_2 tension in the water would have the effect of reducing both the speed of oxygen absorption and the amount carried by the hemoglobin. Swingle (1947) concludes that a greater increase in CO_2 tension of the water in order to increase algal production would eventually result in death of fish by asphyxiation, therefore, great care must be taken not to increase the tension too rapidly or too high.

Nitrogen.--Nitrogen is a necessary element in the productivity of a pond. It is obtained through the putrefaction cycle. The nitrogenous compounds in waste matter are broken down by the anaerobic bacteria into ammonia and other compounds. In the presence of oxygen, the aerobic bacteria oxidise ammonia into nitrites and nitrates. Nitrate nitrogen is available to the various forms of life in the pond. Again, the denitrifying bacteria break down nitrates eventually producing free nitrogen.

The nitrogen cycle is very important in the life of the pond. Adequate quantities of nitrate nitrogen are essential for its productivity (Pearsall, 1932). The best production of plankton is obtained when the water contains 4 p.p.m.

nitrogen along with 1 p.p.m. potassium.

The healthy growth of fish can be expected in waters containing less than 2 p.p.m. dissolved ammonia. The toxic effect of ammonia compounds is at a maximum when pH ranges from 7.4 to 8.5 (Hora and Pillay, 1962).

H₂S.--Sulfurated hydrogen is a severe limiting factor in fish ponds. It is formed during decay of organic matter. It accumulates in the pond bottom having a thick layer of organic deposits. A concentration of 6 p.p.m. of H₂S can kill common carp within a few hours. Mechanical aeration of the pond helps reduce its H₂S content.

Phosphorus.--Phosphorus is a crucial factor in the biogeochemical cycles. This importance stems from the fact that phosphorus is vitally necessary in the operation of energy transfer systems of the cell and that it normally occurs in very small quantities. The latter factor means that there is a chance of deficiency of the nutrient which in turn could lead to inhibition of phytoplankton increase, resulting ultimately in decreased productivity in the pond or lake.

Phosphorus occurs in several forms but only soluble phosphate phosphorus and soluble organic phosphorus are of importance in natural waters. In water, phosphorus may enter into combination with a number of ions but more conspicuously perhaps with iron and with the usually abundant calcium. The pH of the water determines to a great extent the nature of

the phosphate compound. In neutral and slightly alkaline conditions, calcium phosphate is probably prevalent, while extremely high pH usually results in the formation of sodium phosphate. In acid waters, phosphate attraction swings toward iron to form ferric phosphate.

The concentration of total exchangeable phosphorus in natural waters is determined primarily by (1) basin morphometry, as it relates to volume and dilution and to stratification or water movements; (2) chemical composition of the geological formations of the area, as they contribute dissolved phosphate; (3) drainage area features in relation to introduction of organic matter; and (4) organic metabolism within the body of water and the rate at which phosphorus is lost to sediments. See further Pearsall (1932); and Hutchinson (1957).

Potassium.--Potassium is another chemical element responsible for the productivity of a pond. Sandy soil is usually poor in it but clay soil is usually rich in it. It is important for the growth of aquatic flora. It is released into the water directly from the plant tissues when they decompose. A concentration of 1 p.p.m. K in combination with 1 p.p.m. P and 4 p.p.m. N is believed to be most favorable for plankton production.

3. The Soil

Fish culture can use soils of poor or marginal agricultural value such as undrainable marshlands, sandy and acid soils. Schäperclaus (1959) writes that the large and important fish farming in Lusatia, Germany, is situated on the poorest soils from the point of view of agriculture and forestry. De Bont (1952) reports that ponds constructed on lands valueless for other purposes in the Congo could produce as much as 9,000 kg/ha/annum with feeding.

It is, however, not suggested that only poor soil is good for fish culture but the basic requirements of fish culture are less exacting than in agriculture and that, fish culture can bring such unproductive lands into good use. Poor lands under fish culture can yield as good a cash return as good land under agriculture (Hickling, 1962).

For fish culture the soil should be impermeable to water or be made so. Therefore, badly drained, water-logged soils are the best. Sandy soils will also be good provided they have a water holding impermeable layer just under them. Sandy soils produce the sweetest fish (Birtwistle, 1931).

a. Pond Bottom

The productivity of a pond is related to its bottom. The normal bottom of older ponds has two distinct layers: (1) the mineral ground floor or the original bottom, and (2) the overlying colloidal mass of organic mud which is the result of metabolic processes within the pond.

Metabolically, the task of the whole bottom is three-fold: (1) emission of nutritional matter from the bottom into the water; (2) fixation and chemical combination of allochthonous and autochthonous nutritional matter; and (3) offering shelter and food to bottom fauna, especially to mud dwellers.

The pond muds can again be divided into two layers, namely, the more or less thin oxidizing layer over a thick reducing layer. As long as there is any oxygen in the water, the over-lying water is sealed off from the reduced mud by the oxidized layer, but, in the absence of oxygen in the water, the reduced layer may reach the surface and build up an oxygen debt. If the soil is rich in sulfur, dangerous conditions for fish could appear (Hickling, 1962).

Ferric hydroxide in the pond mud is mainly responsible for the formation of oxidizing layer blocking the free ion-exchange between mud and water (Mortimer, 1941-1942). If oxygen supply is cut off from the oxidizing layer, the reduced iron cannot hold the absorbed ions such as phosphates and silicates. Consequently, they are diffused into the water and utilized by plants and thence by fish.

The release of nutrients absorbed in the pond mud can also be brought about by liming. When the pH of the water rises from 5 to 7 and then to alkaline side, the ion absorption capacity of mud falls (Ohle, 1938).

Very little investigations on the physico-chemical

properties of soil and water of fish ponds have been carried out in Pakistan. The soil is generally alluvial but varies in structure and physical conditions in different parts of the country. It is generally alkaline in reaction and deficient in organic matter and nitrogen (phosphorus and potash being adequate) in West Pakistan and in lime, phosphorus and humus in East Pakistan where it is acidic in nature (Siddique and Mohammad, 1951). Accurate information on the optimum properties of soil and water for the culture of different species of fish is highly desirable. A classification of water, based on its capacity for the production of fish food and the level of natural or artificial replenishments in terms of nutrients needed to maintain them in a state of optimum productivity will be of immense help in putting the fish culture on a scientific basis.

b. Drying the Pond Bottom

The importance of drying the pond bottom was early recognized by the Chinese fish culturists. Fish ponds should be wholly drainable, and they must in fact be drained to collect the whole crop of fish. At this time, the pond may be left to dry for a while. Drying kills many harmful insects, fish parasites and disease bacteria. During the drying period, the routine maintenance work of the pond like repairing the banks, drainage channels, etc. will be easy. The chief advantage, however, is the restoration of the pond. Wunder

(1949) states that (1) during the dry period, the accumulated organic matter in the pond bottom is completely oxidized and the contained nutrients released, and (2) on the dry bottom, plants will soon grow, and when the pond is refilled, these plants decompose and provide a good medium for the development of fish food.

Schäperclaus (1933) and Huet (1960) also mentioned the mineralizing effect of the exposure of pond bottom to the sun.

Draining may cause the loss of fish food material, but it is off-set by the fact that the plankton organisms have resistant spores, and many insect larvae can burrow into the pond mud. As these creatures grow very fast, they soon repopulate a pond when it is refilled.

During the dry period, which generally falls in late spring and in summer, quick growing leguminous plants may be grown in the pond bottom. This will (1) thoroughly dry out the soil and aerate it by the growing roots of the plants, (2) give the farmer additional income from the plants, and (3) increase the productivity of the pond if the crop is ploughed into the bottom as a green manure.

4. Aquatic Organisms and Their Management

The aquatic organisms of a pond include its phyto- and zoo-biota.

a. Phytobiota

These include bacteria, planktonic and sessile microscopic and macroscopic algae and also submerged, floating and emergent macrovegetation.

Bacteria.--The important and useful functions of bacteria consist in dissolving (mineralising) dead remnants of organic substances upon which all vegetation depends. Lack of bacterial activity will lead to peat and morass conditions. They are abundant in tropical waters and may either be free-living, attached to higher organisms or are present in the pond bottom.

Phytoplankton.--Phytoplankton has two functions:
 (1) it is used as feed by the zooplankton and fish, and
 (2) it creates the productive, fine colloidal slime at the bottom of the pond. Phytoplankters may be either net-plankton or nonnoplankton. The latter can pass through a net of even the finest meshes (0.064 inch mesh), but the former cannot.

Algal forms like Oedogonium, Spirogyra, Aphanothece, Aphanocapsa, Oscillatoria and Lyngbya may be seen in large or small quantities in a pond throughout most of the year. Phytoplankters have two blooms a year--a lesser one in hot weather and a greater one during the cold weather. The cold season is favorable for the growth and reproduction of a number of green filamentous algae like Zygnaema, Spirogyra, Bulbochaete and Oedogonium. Desmids, Chlorococcales, and

some blue-green algae like Anabaena occur abundantly during this season. During the hot season, most of the desmids disappear and the blue-greens predominate along with Euglena of the family Eugleniaceae. During the period of heavy rains, algal growth is at a minimum (Hora and Pillay, 1962).

Phytoplankters are detrimental to the metabolic cycle only during water bloom. Water bloom creates turbidity and cuts down light penetration. The decaying water-bloom through its oxygen consumption and release of toxins may also be injurious to fishes (Prescott, 1948; Ingram and Prescott, 1954).

Macrovegetation.--Macrovegetation in a pond may be best divided into the three classes of: (1) emergent plants; (2) floating plants; and (3) submerged plants. The following emergent plants are of importance in a fish pond in East Pakistan (Anonymous, 1957; Chokdar, 1958):

Water lily (Nymphaea spp.)

Prickly water lily (Euryale ferox)

Water primrose (Limnanthemum spp.)
(Ipomaea reptans)
(Jussiaea repens)

Water chestnut (Trapa bispinosa)
(Trapa natans)

Water milfoil (Myriophyllum sp.)
(Limnophyla heterophylla)

Arrowhead (Monochoria hastata)
(Sagittaria sagitifolia)

Pondweed (Potamogeton spp.)

The emergent plants are rooted in the bottom of the pond and their leaves and floral shoots rise above the water level. They grow more abundantly in the shallow parts of the pond. They are noxious from the view of pond culture and for the following reasons (Schäperclaus, 1933; Sarig, 1957):

- 1) They cause bottom deposits by sinking down to it at death.
- 2) They shade the water to such an extent that the development of the fish and productivity of other aquatic organisms are noticeably retarded.
- 3) They often reduce the oxygen content of the water.
- 4) They hinder fish in finding their food.
- 5) They deprive the pond of valuable plankton.
- 6) They penetrate the bottom extensively with their roots and reduce the productive layer of decomposed matter. This further reduces productivity.
- 7) They make cleaning and proper supervision of pond more difficult. Predacious fish also find hiding places in them.
- 8) They increase mosquito menace.

However, a moderate growth of these plants will increase the chances for the development of zooplankton.

The following floating plants are important:

Water hyacinth (Eichhornia speciosa)

Water lettuce (Pistia stratiotes)

Duckweed (Lemna minor)
(Wolffia arrhiza)

Water velvet (Salvinia natans)

Pondweed (Azolla pinnata)

Of these, water hyacinth and water lettuce are the most important. These plants float on the pond surface and are rooted in the water. They are harmful since they shade the pond almost completely without offering any compensating advantages.

Under the submerged plant category comes all the weeds which chiefly grow beneath the water surface. The important submerged plants are:

Bladderwort (Utricularia stellaris)

Coontail (Ceratophyllum demersum)

Tape grass (Vallisneria spiralis)

Pondweed (Hydrilla verticillata)

(Ottelia alismoides)

(Naias spp.)

(Lagerosiphon sp.)

(Chara sp.)

Submerged plants are rather helpful for the following reasons:

- 1) They are the natural food of many animals in the pond.
- 2) They largely support the pond with necessary oxygen.
- 3) They are the ideal haunts for the herbivorous fauna.
- 4) The decayed plants are a good fertilizer for the following year.

An excessive growth of submerged plants will however become

noxious. It will shade the deeper layers of the water thus creating difficulties for the fish to find food. It will reduce the oxygen content of a pond at night.

b. Control of Phytobiota

Algae

Preventive measures.--Fertilization of ponds should be avoided when growth is excessive.

Curative measures.--(1) Mechanical--Limited water areas can be cleared by means of nets and screens. (2) Biological--Introduction of algivorous fishes like Tilapia. (3) Chemical--Copper sulfate at the rate of 1-2 p.p.m. is quite effective. A higher concentration than this may be toxic to fish. A great defect of chemical control is that the dead algae cause oxygen depletion during decay (Prescott, 1948; Kessler, 1960). It is advisable to use copper sulfate at least a month before the bloom is expected.

Macrovegetation

Preventive measures.--Shallow ponds encourage the growth of rank vegetation. Removal of excess mud, and deepening of pond will decrease the weed growth considerably.

Curative measures.--(1) Manual labor--Control by this method has been found suitable and economical in fish ponds in the case of floating plants like Pistia and Eichhornia (Ahmad, 1955). Nymphaea can be stopped growing by repeated underwater cutting of stems. (2) Shading--Submerged plants

like Ottelia can be controlled by shading it with Pistia. Prevention of photosynthesis by shading may also control Hydrilla, Naias, Vallisneria, Ceratophyllum and other vegetation. (3) Biological--Weed control by herbivorous exotic fish Tilapia is not yet successful in small ponds of East Pakistan. However, it is too early to draw any definite conclusion regarding this. Schuster (1952a) indicates that Tilapia and the Chinese carp (Ctenopharyngodon idellus) are highly successful weed controllers in Indonesia. De Bont (1949) observed that Tilapia can clean up satisfactorily the semi-emergent vegetation in ponds. Van der Lingen (1957) found that ducks are very effective in controlling pondweed. They clear the pond, manure the water and provide income from the meat. He also got better fish crop with ducks in the pond. (4) Chemical control--Fertilization: In the South-East United States, fertilization is a profitable way to control water weeds. Besides darkening the water by increasing turbidity, it increases the fish food. This results in greater fishing success and higher yields. Highly fertile waters grow millions of microscopic algae. These shade the pond bottom and prevent the seeds of water weeds from germinating and growing. Usually, 800-1200 pounds of 8N-8P-2K fertilizer are applied per surface acre of pond in two to three applications per year (Davison et al., 1962).

In East Pakistan, 10N-8P-4K fertilizer was found to

produce sufficient Microcystis to form a thick cover after four applications in two months, first at the rate of 5 p.p.m., then at 10 p.p.m. (Anonymous, 1958).

Submerged weeds can be suppressed temporarily by ploughing in a high dose of a mixture of copper sulfate and ammonium sulfate during the drying period. Superphosphates at the rate of 500 p.p.m. are effective against Hydrilla.

Hormone weedicides: Fernoxone (sodium 2,4-D) at a concentration of 2 p.p.m. is effective in killing submerged plants like Hydrilla, Naias and Potamogeton and floating plants like Pistia and Eichhornia without any adverse effect on fish or other pond biota. Planotox (ester of 2,4-D in liquid form) is effective on various submerged plants when sprayed at the rate of 9-10 p.p.m.

Sodium arsenite: It is very effective in concentrations of 5 p.p.m. in completely destroying several submerged weeds like Hydrilla, Ottelia, Ceratophyllum, and the alga, Spirogyra, in about two weeks without any adverse effects on carps, Tilapia, catfishes, and snakeheads. It is a dangerous caustic poison and should be used with caution. It may also reduce fish food production (Anonymous, 1958).

Chemical control of aquatic weeds cannot be recommended for ponds whose water is used for domestic purposes as well as for watering the livestock.

c. Zoobiota

Zoobiota consists of floating, attached and bottom dwelling organisms. Copepods, cladocerans, rotifers and flagellates constitutes the main microfauna. Zooplankters exhibit a seasonal periodicity in their abundance similar to that of phytoplankters. Zooplankters have a great role to play in the productivity of a pond in the sense that they form the major portion of food of the young fish. Among the macrofauna, worms, molluscs, crustaceans, and insects are of importance. Extraneous fishes are either weed feeders or predatory.

Control of zoobiota in nursery ponds has been discussed elsewhere. Some weed fishes are larvivorous and help check the breeding of malaria-bearing mosquitoes. Khan (1947) observed that Colisa fasciata, Ambassis baculis and Barbus sophore can each eat 148, 136, and 90 eggs of Anopheles per day in the Punjab, West Pakistan. Similar findings were also reported by Ahmad (1958) from East Pakistan. Hofstede and Botke (1950) observed that Tilapia mossambica could reduce the mosquito menace in some Javanese ponds by controlling the floating filamentous algae on which mosquitoes lay eggs.

Fishes like the snakeheads (Ophicephalus spp.), catfishes (Wallago attu, and Clarias batrachus) and the climbing perch (Anabas testudineus) are probably the most destructive predacious pond fishes. There is no adequate way to estimate

the losses caused by these fishes but the damage is probably considerable and for the following reasons:

- 1) They exploit much of the natural food of the pond.
- 2) They prey on fry and fingerlings of the cultivated carps.
- 3) They help in transmitting diseases and parasites.

d. Control of Predacious Fish

Preventive measures.--(1) Periodic draining and cleaning the pond. (2) Screening the inlet of the pond before the onset of the monsoon. (3) Repeated fishing.

Curative measures.--These are inadequate in those ponds which cannot be drained. Besides, predacious fishes are extremely hardy, and can even survive drought by burrowing deep into the wet mud.

Use of toxins: Numerous types of toxic chemicals are now in use to clear fish-bearing waters of undesirable fishes (Applegate et al., 1957; Bridges, 1858). The best known fish toxin is rotenone, contained in Derris elliptica and D. uliginosa. It is generally agreed that a concentration of 0.5 p.p.m. rotenone by weight is lethal to most kinds of fish. It does not penetrate the deeper depths of pond or lake when applied at the surface. Water temperature should be at least 75°F at the surface for best results.

Rotenone-treated fish reacts as follows:

- 1) Constant gasping and gulping of air. Rotenone does not deplete oxygen but the fish cannot utilize it because the passage of the oxygen-bearing red blood cells (R.B.C.) has been effectively blocked by the constriction of the capillaries in the gills.
- 2) Loss of equilibrium. The cessation of the passage of the R.B.C. cuts off the supply of oxygen to the brain with a consequent loss of function of the organs of equilibrium.
- 3) Fish can recover fully from the effects of rotenone narcosis within a few hours (Krumholz, 1948).

Rotenone poisoned fish may be used for human consumption (Sarig, 1954). Alikunhi (1957) observed that at 20 p.p.m., the toxicity of derris powder persisted for 8-12 days at Indian temperatures, while lower doses up to 6 p.p.m. per acre did not make water toxic for more than four or five days.

Mohanti and Mohanti (1950) observed that 5 p.p.m. hydroquinone could kill all the carps and catfishes in 2-6 hours, but most of the snakeheads remained alive at this concentration. Hydroquinone depletes oxygen, but it is restored within 20 hours. It does not affect phytoplankton.

Nowadays much more potent toxins are available. They are primarily insecticides and when they are used in rice fields, they kill or threaten fish culture there (Edmondson,

1959; Kuroda, et al., 1956; Matida and Kimura, 1957).

Soong and Merican (1958) observed that endrin at 0.008 p.p.m. used in the form of emulsifiable concentrate called endrex cleared the pond thoroughly. It is cheaper than derris root. It is particularly useful in dealing with large bodies of water 10 to 30 feet deep where the cost of piscicides used is an important consideration. The fish killed with endrin is not toxic to human beings. The toxic effect of endrin is dissipated in 2-5 weeks after which the pond may be restocked. Before using such powerful piscicides, all the fish that can be caught by other means will be removed for sale.

All precautionary measures need to be taken before powerful piscicides are applied. The pond must not leak to allow enough toxins to escape into public waters killing fish there, as this may lead to prosecution.

Birds like cormorants, eagles, herons and kingfishers, and snakes and others are not pond dwellers but they feed mainly on fishes. They may be either shot or caught by setting traps.

5. Preparation of Pond for Stocking

a. Preliminary Steps

The preliminary steps in the preparation of a pond for stocking are: (1) checking inlet and outlet arrangement; (2) repairs or improvements; (3) control of undesirable

aquatic biota; (4) correction of physico-chemical properties of water and soil; and (5) draining and desilting.

b. Liming

Demoll (1925), Schäperclaus (1933), Walter and Nolte (1930) and Wunder (1949) devoted many pages to liming ponds. In general, calcareous waters with alkalinities of more than 50 p.p.m. are most productive of fish. Waters with alkalinity of less than 10 p.p.m. rarely produce large crop (Mortimer and Hickling, 1954).

The beneficial effects of liming has been attributed to various factors, including the direct utilization of calcium as plant and fish food (Adan, 1935). These are:

- 1) The production of neutral or alkaline reaction in a formerly acid medium.
- 2) The speeding up of the decomposition processes in the muds.
- 3) The establishment of a strong pH buffer system.
- 4) The production of bicarbonate- CO_2 reserves, so that CO_2 lack cannot be a limiting factor.
- 5) Counteraction of possibly poisonous effects of excess magnesium, potassium or sodium ions.
- 6) Base-exchange phenomena and flocculence effects in muds which liberate other absorbed plant nutrient into the water.
- 7) Fixation of harmful organic and inorganic (humic) acids.

- 8) Poisoning competitors and enemies of the fish.
- 9) Disinfection of the pond against disease.

Liming is an essential preliminary to successful pond manuring. Lime is generally applied in the form of ground limestone (CaCO_3) slaked lime (Ca(OH)_2) or quick lime (CaO). Calcium carbonate becomes calcium bicarbonate by slow dissolution. Quick lime is more advantageous as it produces the same results in a pond with half the quantity in terms of weight.

Lime can be applied on the pond bottom, added to water at the inlet or just be spread on the water surface. For best results, quick lime should be applied after draining, and the pond should be allowed to dry for about two weeks. A dosage of 200 kg. CaO per hectare has been recommended; a quantity of 1000-1500 kg. CaO will be required for ponds with acidic soil and water (Hora and Pillay, 1962). Schäperclaus (1933) suggests the following dosage (Table 20). Macan et al. (1942), however, suggested the following doses (Table 21).

Swingle (1947) reports that the addition of limestone to ponds receiving inorganic fertilizers always decreased fish production in experimental 1/4 acre ponds. He considers that the quantity of CO_2 may be a limiting factor in fish production in ponds with inorganic materials, acting through the food chain which begins in most cases with phytoplankton production. He may have had PO_4 complexing with

TABLE 20. pH of soil and approximate quantity of CaO required to neutralize it^a

pH of soil	Lime requirements in doppelzenter (dz.) or 200 kg. CaO per hectare		
	Heavy loams or clays	Sandy loams	Sand
Less than 4.0	40.0	20.0	12.5
4.0-4.5	30.0	15.0	12.0
4.5-5.0	25.0	12.5	10.0
5.0-5.5	15.0	10.0	5.0
5.5-6.0	10.0	5.0	2.5
6.0-6.5	5.0	5.0	0.0

1 dz. = approximately 2 cwt; 1 dz/ha = 89.2 lb/acre. If limestone is to be used, the doses should be double.

^aSource: Schäperclaus (1933).

TABLE 21. pH of mud and limestone requirements^a

pH of mud	Calcium carbonate required (100 kg. per hectare)
Less than 4.0	60-120
4.0-4.5	48-96
4.5-5.0	36-72
5.0-5.5	30-48
5.5-6.0	16-30
6.0-6.5	14-16

If slaked or quick lime is to be used, the above amounts should be multiplied by $\frac{3}{4}$ or $\frac{1}{2}$ respectively.

^aSource: Macan et al. (1942).

CaCO_3 to tie up PO_4 as insoluble salts.

c. Fertilization

The fertilization of fish pond is necessitated by the fact that there is a constant consumption of nutrient in it. Periodic draining helps the fish culturist in mobilizing the nutrients in the pond soil by drying and mineralization. But in intensive fish culture, it is often necessary to apply fertilizing agents to the pond to enhance its productivity.

Just as in agriculture, organic and inorganic fertilizers make additional production of fish possible that cannot be obtained without fertilization. In Pakistan, cow dung, poultry manure, spoiled oil-cakes, green grass and pondweeds are commonly used as organic manures. Inorganic fertilizers like sodium nitrate, ammonium sulfate, ammonium superphosphate and their standard mixtures, commonly known as N-P-K fertilizers, are rarely used as manures in fish ponds.

Researches on the use of manures in ponds are yet to begin in Pakistan. Pioneer investigations in Central Europe and North America regarding pond fertilization have been summarized by Neess (1949) and Swingle (1947) respectively. These investigations have yielded valuable information on the effect of fertilizers, especially N-P-K fertilizers, under conditions existing in temperate climates. It has

been found that the fish carrying capacity of pond in Alabama has been increased 300-400% as a result of fertilization.

Organic manures.--Traditional practices of fertilizing fish ponds with cow-dung, stable manure, poultry manure, oil-cake, green grass, dry leaves, etc. are in vogue in East Pakistan. Such combination of different materials of animal and plant origin ensure C-N-P-K balance through putrefaction, whereas organic fertilizers supply only N-P-K and their nutritive value is soon dissipated (Hora, 1951).

The practices of using banana juice and soap waste in ponds are helpful in building up a reserve of readily available bicarbonate alkali. Banana stem has been found to contain a large amount of bicarbonate ion (Hora, 1951).

Organic manures use up a considerable amount of dissolved O_2 during decomposition. Major carps can live for 24 hours in water devoid of CO_2 and containing 1 p.p.m. O_2 . Another benefit of using organic manures is that organic carbon retains nitrogen in the medium for a longer period. Green grass, dry leaves and rice straw are helpful in supplying silica and iron for the production of diatoms and other algae which are the food of many cultivated fishes.

Saha et al. (1951) estimated moisture, N, protein, Ca, P, and K in 10 organic substances used as pond fertilizers in West Bengal, India. Of the materials analyzed, fish meal containing 7% N appears as the richest source of N,

followed by mustard seed-cake and water hyacinth (Eichhornia crassipes), with 4.76% and 4.0% respectively. With regard to Ca, crab meal is the best source containing 12.3%, followed by Hydrilla, fish meal and Ceratophyllum with 4.8% 3.0% and 2.6% respectively. Ceratophyllum is very rich in P, 3%. With regard to K, banana leaf and Arum stem are the best sources containing 5.1% and 4.9% respectively calculated as K_2O , and then comes the water hyacinth with 4.2%.

Fish meal, crab meal and mustard seed-cake will be quite costly for an average pond owner. Water hyacinth, Hydrilla, and Ceratophyllum are found abundantly in fish ponds, lakes, swamps and canals. These may be collected, dried or composted. To these may be added sufficient quantities of similarly dried or composted banana leaves and Arum stems. This will be a good fertilizer for ponds in rural areas.

The disadvantages of using organic manures are two: (1) they stimulate heavy growth of aquatic vegetation retarding fishing efficiency, and (2) during hot weather, the rate of decomposition may be so rapid as to deplete oxygen and saturate the water with CO_2 , resulting in the asphyxiation of fish. In the application of organic manures, it is necessary to balance the oxygen budget and the oxygen concentration should not be below 3 p.p.m.

Ordinarily, a dose of 1000 kg. of cow-dung or horse manure per hectare is recommended. Where cow-dung, sheep or

poultry manure are not available, compost can be used as a substitute. Any available plant matter like leaves, grass cuttings, aquatic weeds, etc. can be composted which will be ready for use in about three months. About 5,000 kg. per hectare may be needed to give rise to a sufficiently abundant growth of fish food in ponds.

Inorganic fertilizers.--The important fertilizing elements can be supplied to a pond by the application of N-P-K (6-8-4) fertilizers. A number of formulae for inorganic fertilizers for fish pond manuring have been evolved and the following two have yielded good results in the United States (Swingle, 1947):

- 1) 100 kg. of 6N-8P-4K and 10 kg. of sodium nitrate.
- 2) 100 kg. of ammonium sulfate
 150 kg. of superphosphate (16%)
 12.5 kg. of muriate of potash and
 37.5 kg. of finely ground limestone.

A mixture of organic and inorganic manures consisting of three parts of animal manure and one part of superphosphate per hectare per annum have also been found quite effective (Hora and Pillay, 1962).

Fertilizers, organic or inorganic, are most effective if they are applied after draining the pond. If it is not possible, they can be applied from a boat. The first application can be made after the monsoon. Several applications will cause a plankton bloom and if the turbidity is such that it

makes a Secchi Disk disappear at a depth of about 45 cm., the pond is considered properly fertilized. Ball (1949) reported that inorganic fertilizers increased planktonic fish food in some Michigan lakes by as much as 3.3 times.

6. Stocking

In pond culture, the production of fish is the main objective and the selection of species will depend on the conditions under which the fish will have to live and grow. For instance, the type of food available in the pond and its general biota would determine the association of fish to be introduced into it. For practical purposes, a pond can be divided into surface, midwater and bottom zones. The surface feeding species can be plankton feeders or they can take floating vegetation. Similarly, a bottom feeder may live on snails, worms and insects or organic debris. In selecting species, one must bear in mind the following points:

- 1) The species should be tolerant of one another.
- 2) They should not compete for food with one another.
- 3) Between themselves, they should use up all kinds of available food materials in the pond and thereby contribute to the general sanitation of their environment.

It will thus appear that proper stocking not only means selection of species but also the number of each kind depending upon the extent and nature of fodder resources of

the pond. Artificial feeding of pond fish is almost nil in Pakistan, therefore stocking methods should be devised in such a way that the fish can grow healthy with the food produced in the pond naturally or through fertilization. To evolve sound stocking techniques, the basic information necessary is the food requirement (quantity of food consumed per unit time) of different age or size groups of the fish and the quantity of fish food that is or could be produced in the pond.

Stocking systems in East Pakistan are now based on trial and error as the above type of information is lacking. Based on the expected growth increment, the total production and the expected mortality figures, the number of fish to be stocked can be computed as follows:

$$\text{Number of fish to be stocked} = \frac{\text{Total expected increase in weight}}{\text{Expected increase in weight of individual fish}}$$

For example, if in a pond of one hectare area, a total production of 1,000 kg. of carp can be obtained and it is to be stocked with fingerlings of 30 g. weight with a view to harvest the fish when they have attained a weight of 330 g., the expected mortality being 10%, the number of fingerlings to be stocked will be:

$$1,000/0.3 + 100 = 3,433.$$

The four major carps (Catla catla, Labeo rohita,

Cirrhina mrigala and Labeo calbasu) are profitably cultured together, since Catla is a plankton feeder, rohu column feeder, mrigal debris feeder, and kalbaus mollusc feeder.

Alikunhi (1957) suggests that in Bengal (East Pakistan and West Bengal, India) 30% Catla, 30% rohu and 40% mrigal may be stocked in ponds. Satisfactory results are obtained when these three species are stocked in equal numbers at the rate of 3,000 per acre. At that density of stocking, rohu and mrigal grow quickly but Catla grows slowly when the density of stocking exceeds 1,000 per acre. The general yield varies from 1,500 to 2,500 pounds per acre per annum depending on climatic conditions. Hora and Pillay (1962) write that allowance should be made in the stocking system for an annual mortality which may be more than 30%, also losses by reduction in the volume of water in the pond as a result of evaporation during summer which may be computed as about 10%. A proportion of 30% Catla, 60% rohu, and 10% mrigal is considered very profitable. In a pond of one hectare in area, about 1,875 Catla, 3,750 rohu and 625 mrigal, all 8 to 10 cm. in length may thus be stocked. If kalbaus is included, rohu may be decreased to 50%. As regards other cultured fishes, a stock density similar to that adopted for Catla, rohu and mrigal is recommended though the optimum is not yet determined. Considering the natural food supply, the following stocking rates are suggested by Ahmad (1957a) for East Pakistan's fish ponds (Table 22).

TABLE 22. Rate of stocking of ponds and expected
yield per acre per year^a

Color of pond water	Nature of vegetation	Species of fish to be stocked	%	*Carp 4-5 in. long (number)	**Carp 6 in. long and over (number)	Expected annual yield (lbs.)
Greenish	Permanent abundance of plankton	Catla 50 Rohu 30 Mrigal & Kalbaus 20 Total 100		900 540 360 1,800	600 360 240 1,200	1,440
Clear	Higher aquatic plants sufficient but under control	Catla 30 Rohu 35 Mrigal & Kalbaus 30 Total 100		396 462 462 1,320	264 309 309 882	960
Brownish	Zooplankton sufficient, phytoplankton comparatively less	Catla 40 Rohu 30 Mrigal & Kalbaus 30 Total 100		384 288 288 960	252 189 189 630	720
Clear	Neither plankton nor higher plants abundant	Catla 30 Rohu 35 Mrigal & Kalbaus 35 Total 100		198 231 231 660	132 153 153 438	480
Muddy	Almost without any aquatic vegetation	Catla 33 Rohu 34 Mrigal & Kalbaus 33 Total 100		108 110 108 326	72 73 72 217	240

*% Loss estimated at: 1st month after introduction 25 **% Loss estimated at: 1st month after introduction 15
 2nd month after introduction 10 Rest of year 15
 Rest of year 15

^aSource: Ahmad (1957a), modified.

7. Metabolism and Growth

a. Food and Feeding

Pond-fish culture differs from fisheries in natural waters in that basic production capacity of the pond may be augmented through fertilization and pond care, or the natural food may be supplemented with artificial food. In both cases, a knowledge of the basic nutritive requirements of the pond fish is required.

Metabolism of pond-fish consists of two components: part of metabolism serves to sustain the body of the fish and its functions and the rest takes care of growth and further development. The second function is the primary concern of the pond owner (Schäperclaus, 1933).

The ratio of food consumed by the fish to the fish flesh produced is called forage ratio. The term "food quotient" expressing the unit weight of the fish food required to produce a unit weight of fish flesh denotes the same idea and indicates the commercial value of the fish foods. See also Lagler (1956).

The food requirement of a fish (by weight) is often judged by what is known as the sustenance ratio which can be obtained by the following formula:

$$\text{Sustenance ratio} = \frac{\text{Crude fat} \times 2.25 + \text{carbohydrate}}{\text{Crude protein}}$$

Sustenance ratio varies with age. Cultivated fish can be broadly divided into three categories: (1) those with low sustenance ratio of the order of 1:2 to 1:4; (2) those with medium ratio of about 1:5 to 1:6; and (3) those with high ratio of 1:8 to 1:12 (Schäperclaus, 1933). Such a classification of fish is not yet available in Pakistan, but it is supposed that the major carps belong to the second and third categories.

There is an important difference between natural food on which major carps largely depend, and the artificial food which is relatively low in protein content. The relation between the nutrients plays an important part in their utilization by and growth of the fish. In the natural feeding, the ratio of food to fish (by weight) varies mostly from 1:1 to 1:1.8, while in the artificial feeding considerably lower ratios are met with (Mann, 1961).

Carps cannot utilize animal protein since they have anatomically or physiologically no stomach. The extent of fat solubility and utilization is unknown. Fat content in the food, natural or artificial, is rarely above 2%. Carp can utilize 60-70% fat-free extractives.

In plant foods, the content of crude fibers plays an important role. It is digested by carp up to 60%, presumably not through enzymes of their own but with the help of symbiotic microorganisms. Chitin is not digested. As to the role of minerals, very little is known, although it is

obvious that calcium is important for bone formation.

Mann (1961) writes that the type of food also plays a part. In artificial feeding of common carp, mincing is important. If, for example, lupine seeds were finely cut, the utilization of protein was 84%; when more finely chopped, it rose to 93%. The digestibility of protein is reduced when the food is overcooked, or submitted to excess heat in drying.

The individual characteristics of the fish as race, age, etc. have a certain effect on the fat deposition in the body. The larger the fat accumulation, the better the nutritive requirements are met.

The degree of food conversion into fish flesh depends on a number of factors, the most important being temperature. Fish, being cold-blooded, follow, within certain limits, Van't Hoff's Rule of Q_{10} in consumption of energy. An increase in temperature by 10°C almost doubles the energy metabolism. In the same way, growth is related to temperature, an increase in rate taking place only as long as the optimum is not reached.

In pond cultural practices, three types of fish are recognized: (1) those that relish and grow well on artificial foods, (2) those that grow best on a diet composed of both artificial and natural foods, and (3) those that take only natural foods. Catla, rohu and mrigal belong to the second category. In selecting food for feeding, its dietetic

value and the economic practicability of its use in commercial fish culture must be considered. Schäperclaus (1933); Bondi et al. (1957); Tamura (1961) and Hickling (1962) have discussed in detail the artificial fish foods and their nutritive values.

b. Growth

In pond culture, growth is measured in terms of conversion efficiency (ratio) which indicates how many food units are required to obtain one unit of fish flesh. Growth can slow down or stop completely under unfavorable natural conditions when food supply meets merely the sustenance needs, evidently without any harmful effects on the fish. Overfeeding does not enhance growth above certain limits, only some reserve substance such as fat or glycogen is deposited. Consequently, fattening, as used in the rearing of land animals cannot be applied to fish. Besides, an increased fat accumulation, in general, is not desirable in fish flesh. On the other hand, in starving carp, the weight reduction takes place primarily at the expense of fat, later protein in muscles and viscera may also disappear (Schäperclaus, 1933). The lowering of feeding intensity or the non-availability of certain types of food often affect growth considerably. The density of fish population in a pond is a very important factor which influences the growth rate. Overcrowding causes competition for food and space. Yashouv (1958) and Rose

(1959) have shown that greater concentration of excreta resulting from overcrowding is a growth retarding factor. Kawamoto et al. (1957) have shown that growth of fish is much quicker in understocked ponds than in overstocked ones.

From the practical point of view, there is a limit to the density with which fish can be stocked in ponds; for, beyond a certain limit, the gain due to a larger growing population is off-set by the slower individual growth in spite of an excess of food. This limit has been called "carrying capacity" by Yashouv (1959, 1963) who defines it as the biomass of fish that can be supported in a pond. Van der Lingen (1957) has called it "maximum standing crop" which, according to him, is the maximum weight of fish that can be sustained by a pond, this weight of fish being at balance, without gain or loss in weight, with the food produced by the pond or made available to the fish.

The maximum standing crop varies with many factors:

- 1) It will vary with the management of the pond. Yashouv (1959) writes that the productivity of a pond is determined by its carrying capacity and by the time of growth of the fish biomass up to the level of the carrying capacity. It does not describe the features of the pond itself, but rather the character of their management. Fertilizers with or without artificial feeding increase the carrying capacity of the pond.
- 2) It varies with the species of fish. It will be lower

where a fish is stocked which has a natural check in its rate of growth. It will be higher with herbivorous fish than with the carnivorous ones, because the latter get their primary vegetable food after 90% loss of the original calories in the body of the herbivorous. It will increase where two or more species of complementary feeding habits (cf. Catla, rohu and mrigal) are stocked because the food available will be more completely utilized.

- 3) It will vary with water supply. Very shallow ponds do not support larger standing crop of fish.
- 4) It will vary with climatic conditions. Growth of fish in temperate climates is generally less than that in the tropics.
- 5) It will also be affected by the size of the fish. A pond will support a greater weight of small fish than of larger fish, because the greater weight of small fish will have many more mouths to seek for the available food, and so make better use of the resources of the pond.

To ensure a greater yield, fishing ("skimming") from time to time is essential. Yashouv (1959) writes that the daily fish production decreases when the fish biomass approaches the limit of the carrying capacity; it is advisable to remove some fast grown fish from the pond and start again with the small ones.

In view of the fact that several environmental and other factors affect the growth rate of fish, it is rather

difficult to judge accurately the normal growth or even the maximum growth that can be expected for a particular species. Data regarding the weights attained by some of the cultivated species are given in Table 23.

8. Parasites and Diseases

Many practical problems in the field of fisheries such as attempts to increase the productivity of ponds, to improve the stocks of valuable commercial fisheries in natural waters and most of all, to acclimatize fish in new localities require detailed knowledge of the parasites inhabiting the localities involved. It is equally necessary to know in what species of fish and under what circumstances these parasites are able to live and thrive. Few investigations in this important aspect of fish culture have been undertaken in Pakistan.

Diseased or abnormal fish occurs in nature but the diseases of fish bred or fattened in ponds are far more frequent and differ greatly from those inhabiting natural environments where their occurrence is not in an epidemic form.

Among the most important factors facilitating the outbreak of diseases in ponds is the density of populations which is rather encouraged for economic reasons. Crowded ponds provide good conditions for the rapid spread of diseases among the fish many of whom are usually of the same age. Consequently, when environmental conditions (water temperature,

TABLE 23. Annual rate of growth in weight of some cultivated fishes^a

Species	Weight increase (g) during the year			
	I	II	III	IV
<u>Catla catla</u>	1,125-4,100	4,000-5,000	6,750	---
<u>Labeo rohita</u>	900	3,600	5,400	---
<u>Cirrhina mrigala</u>	650-1,800	2,600	4,000	---
<u>Labeo calbasu</u>	450-800	---	---	---
<u>Tilapia mossambica</u>	140	---	---	---
<u>Lates calcarifer</u>	1,500-3,000	5,000	---	---

^aSource: Hora and Pillay (1962).

etc.) become favorable for mass reproduction of the parasite, the disease may spread very quickly and, in a matter of days, the entire population of fish in a pond can be wiped out (Bauer, 1961). Again, there is always a risk of infection from wild fish which may gain entrance into the pond with the water during the rainy season. Such fish may carry infectious diseases. Birds flying from one pond to another may also carry infection.

Good pond management can prevent or minimize the occurrence of disease and remedies are known for most of the common ones. Plehn (1924), Schäperclaus (1954), Davis (1961), and Dogiel et al. (1961) have written excellent books on the diseases of fish and their control.

a. Ecology of Fish Parasites

The animal parasites of pond fish are either external or internal. The plant parasites are generally fungal in character.

The entire environment of an animal parasite is furnished by other living animals. It is not merely the host but also the host's environment that forms the environment of the parasite. This is especially true for the ectoparasites.

The composition of the parasite fauna depend on the geographical location of the habitat, the season of the year, the physico-chemical features of the water, the type of the bottom, and the fauna present in and around the habitat.

Besides, the direct area of activity and the environment of the parasite are also important. The character of the outer tissues of the host, the presence and the strength of the scales, the degree of development of mucus glands, the thickness of the subcutaneous connective tissue layer, all exert a continuous influence on the ectoparasitic fauna and a temporary one on those endoparasites which penetrate the host through the skin (Dogiel, 1961).

b. Deficiency Diseases

These diseases may be caused by some vitamin deficiency in the food, or to some other upsetting factor. One such disease is anemia with very pale color of the gills, kidney and liver. The fish swim erratically and exhibit a high mortality rate.

The remedial measures are good management of ponds, drying, liming, and removal of shading vegetation. The cure is to transfer the suffering fish to running water or to a new, well-prepared pond.

c. Environmental Diseases

Sluggish swimming, skin lesions, and discoloration of the gills may be caused in water with a pH of less than 5. The weakened fish may be attacked by fungi or skin parasites. The corrective measure is to lime the pond so as to increase the pH of the water to about 8.

d. Fungal Diseases

Gill-rot is caused by Branchiomyces sp. which is a filamentous aquatic fungus. The disease, which may readily kill the fish, appears as a red spot in the gills, turning their filaments later into graying white. This causes the fish to suffocate. The disease occurs during summer when heat and decaying organic matter coincide with a shortage of water (van Duijn, 1962).

Molds of the family Saprolegniaceae may attack the skin, and sometimes the gills and eyes, of fish in which the resistance of these organs has been weakened by injury, by other parasites or such adverse conditions as an abnormal pH of the water. The infection is characterized by the growth of thin threads of dirty-white or grayish color from the infected parts, resembling tufts of cotton wool if growth of hyphae is abundant (van Duijn, 1962). See also Khan (1947).

Valuable fish can be cured by suitable treatments with chemicals; phenoxethol and malachite green are at present regarded as the most suitable remedies (van Duijn, 1956). Schäperclaus (1954) writes that 12 kg. of copper sulfate per hectare of pond surface with a depth of one meter will prevent the outbreak of the disease. The treatment should be 3-4 times a year during summer.

e. Bacterial Diseases

Infectious dropsy is the worst bacterial disease of common carp, and is suspected to be associated with Pseudomonas punctata. The symptoms of dropsy are swelling of the belly due to water, ulcer, deformation of the vertebral column and lengthening of the fins. Bacteria also parasitize the peritoneal and opercular cavities of the fish. Bacterial attack increases with the fall in temperature of pond water in winter (Bisset, 1948a).

The preventive measures include screening of inlet of the pond against the entry of wild fish which may carry infection. The control measures are: collection and removal of diseased fish, breeding strains of carp resistant to the disease and injecting the fish with antibiotics (Snieszko, 1953).

In studies of bacterial fish diseases the functional role of antibodies in fresh-water fish was revealed. The importance of this defense mechanism is staving off pathogenic organisms is evident and reasonably well established. Evidently this build-up of immunity may also check the growth of the normal flora (Bisset, 1948b). He also showed that high temperatures encourage the development of immunity. Cushing (1942) established that carp (Cyprinus carpio) produced agglutinins more proficiently at 82°F (28°C) than at 59°F (15°C).

f. External Parasites

Protozoa

Pseudomonas rebae.--This parasite is found on the gills of the fry of major carps. Tripathi (1954) reported that out of 50 Cirrhina reba he examined, 45 carried this parasite. Rohu, mrigal and Catla showed fewer infections.

Trichodina indica.--This is the commonest ciliate parasite infecting the gills of pond fishes and their fry and fingerlings. Tripathi (1954) observed that among the major carps, its incidence varies from 50-90%, the highest being in rohu (Labeo rohita), and the lowest (13%) in kalbaas (Labeo calbasu). Among the snakeheads, the percentage of infection ranges from 10-40%.

Scyphidia pyriformis.--It is found on the skin and fins of the fry of Labeo rohita. The fry of other carps are not infected seriously. Treatment: (a) Bathe in 2-3% salt solution for 10 min. (Tripathi, 1954). (b) Bathe in 0.01% potassium permanganate (Bauer, 1961); Allison (1957a) used 3 p.p.m. (c) Bathe in 1:4,000 formalin for one hour (Davis, 1961). Prevention: (a) Good flow of water in the pond. (b) Avoidance of very shallow ponds. (c) Liming the pond.

Costia sp.--It affects the epithelial cells and mucus glands of the fish, also attaches itself to gills, skin and fins of the host of all ages. It may kill only the young. Treatment: (a) Bathe in 5% salt solution for 5 min. (Bauer, 1961). (b) Bathe in 1:4,000 formalin for one hour (Davis, 1961; Fish, 1940). (c) Bathe in 2 p.p.m. pyridylmercuric

acetate (PMA) for one hour (Clemens and Sneed, 1958).

Prevention: (a) Disinfection of ponds and fishing gear with lime. (b) Quarantine of newly introduced fish.

Chilodonella sp.--This parasite attacks the gills, fins and body surface of the fish (van Duijn, 1962).

Treatment: (a) Bathe in 5% salt solution for 5 min. (Bauer, 1961). (b) Bathe in 1:4,000 formalin for one hour (Davis, 1961). Prevention: (a) Deepening the pond.

Ichthyophthirius sp.--This protozoa attacks the gills, fins, skin, and sometimes the eye of the fish of all ages.

Treatment: (a) Bathe in 1:4,000 formalin for one hour (Davis, 1961). (b) Bathe in 2 p.p.m. PMA for one hour (Clemens and Sneed, 1958). (c) Holding the fish in swift-flowing water.

Prevention: (a) Preventing the parasite-carrying wild fish from entering the pond. (b) Liming the pond.

Monogenic Trematodes

Dactylogyrus spp. These trematodes attack the gills of the fish of all ages throughout most of the year (Jain, 1958). Gyrodactylus spp. These attack the skin and fins of the host. Treatment: (a) Bathe in 3-5% salt solution for 5 min. (b) Bathe in a mixture of 7% NaCl and 30% MgSO_4 solution for 10 min. (Bauer, 1961). (c) Bathe in 1:4,000 formalin for one hour (Davis, 1961). Prevention: (a) Fingerlings should be checked before stocking. (b) Liming of the pond.

Leeches

Khan (1944) observed that the leech (Hemiclepsis sp.)

attacks the lips, nostrils, gills, fins and anus of young and adult mrigal (Cirrhina mrigala), and rohu (Labeo rohita), in some ponds in Lyallpur, West Pakistan. Mortality is reported to be caused by it among the young carps (Saha and Sen, 1955). Treatment: (a) Bathe in 1:1,000 glacial acetic acid for one min. (Khan, 1944). (b) Bathe in 0.5% gammexane (Saha and Sen, 1955). (c) Bathe in 2.5% salt solution for one hour (Bauer, 1961). Prevention: (a) Draining and drying the pond. (b) Liming the pond.

Copepods

Argulus sp.--This copepod is found mainly on Labeo rohita, though other major carps are also attacked. Hora (1943) reported heavy mortality among carps in Bengal caused by it. Southwell (1915) also reported mortality among carps from the Punjab. Treatment: (a) Bathe in 1:1,000 glacial acetic acid for 5 min. followed by a bath in 1% salt solution for one hour (Khan, 1944). (b) Bathe in 0.1 p.p.m. gammexane (Saha and Sen, 1955; Sarig, 1958). (c) Bathe in 0.2% lysol or 0.001% potassium permanganate solution for 5-15 seconds (Bauer, 1961). (d) Bathe in 0.01-0.02 p.p.m. DDT mixed with pond water (Schäperclaus, 1954). (e) Bathe in 1:4,000 formalin for one hour (Davis, 1961). Prevention: (a) Draining and drying the pond. (b) Liming the pond. (c) Keeping the embankments clear of roots of plants thus reducing the area of egg deposition by the copepod (Bauer,

1961). (d) Culturing larvivorous fishes like Colisa fasciata, Ambassis baculis and Barbus sophore in the pond.

g. Internal Parasites

Protozoa

Nyctotherus pangasia.--This ciliate parasite was reported by Tripathi (1954) from the intestine of catfish, (Pangasius pangasius). Though the infection was heavy, he did not observe any pathological effects on the intestinal wall of the fish. The curative and preventive measures for this parasite are not known.

Platyhelminthes

Trematodes that are parasitic in the internal organs of fish belong mostly to the genus Distomum with a life cycle including stages in mussels and snails.

Cestodes (tapeworms) that are very risky from a hygienic point of view belong to the genus Diphyllbothrium. They generally remain dormant in fish until it is eaten by a human being. The latter is infected in case he fails to apply adequate heat treatment to the fish prior to consumption (van Duijn, 1962). Attempts (Allison, 1957b) to cure the fish suffering from these parasites have not been successful.

General prevention of all fish diseases lies in the public sphere; good sanitation will prevent the spread of human excreta without disinfection or other cleaning measures

into free waters, and dogs and cats must be kept away from fish ponds. A healthy fish in a well-managed pond can be strongly resistant to all fish diseases (van Duijn, 1962; Hickling, 1962).

9. Capture and Marketing

a. Capture

Seines, cast nets and drag nets are used for this purpose in Pakistan (see also fishing craft and gear, page 25.) Intermediate fishing is conducted to catch fish for sale, it also serves the purpose of thinning out the stock of fast growing species like Catla, thus quickening the growth of other fishes in the pond. Kawamoto et al. (1957), however, reports that intermediate fishing may reduce the growth of the fish remaining in the pond by as much as 5%, due to irritation, upset and alarm caused to them.

At the onset of the rainy season, fish farmers flow in a good supply of rain water from a nearby source. There is a tendency for the fish to swim toward the inlet and collect at the mouth of it where they are caught by various bamboo traps as well as by cast nets. In this way minnows and other pond fishes are taken.

Harvesting a pond by draining it is also practiced during summer. The fish tend to collect in the water remaining when the rest of the pond lies bare. They may also

collect in depression in the pond bottom. They are then picked up by hand or in dipnets.

b. Marketing

Pond fish can often be marketed in living condition. Live fish fetch a better price than the dead ones. Catfishes, the climbing perch and the snakeheads have labyrinthiform accessory breathing organs enabling them to live out of water or in only enough water to keep their body and gills moist for about a week after the catch. See further fish marketing, page 50.

I. Fish Culture in Lakes, Reservoirs, Swamps and Irrigation Canals

Besides ponds, lakes, etc. are also used for fish culture, but their operations are quite different from those of pond culture. In expansive waters, introduction of cultivable fish is undertaken as a part of a general fishery improvement program rather than for fish culture in its truest sense. See also Zobairi (1953).

1. Lakes and Reservoirs

Lakes and reservoirs can play a significant role in food production provided they are improved and well-managed.

Limnological studies of these waters have so far not been undertaken in Pakistan. Forel (1892), Welch (1948, 1952), Ruttner (1953) and Hutchinson (1957) have written valuable books on the limnology of lakes of temperate zone

from which useful information can be derived for limnological work in Pakistan and other tropical areas.

Lakes and reservoirs differ greatly in size and depth. Their productivity is greatest in the shallow littoral zone.

Thermal stratification occurs in deep lakes in summer and winter, but as most of Pakistani lakes are shallow, a true thermocline seldom develops in them. This enables continuous mixing of waters and circulation of nutrients. These account for higher productivity of these waters.

Biota.--Biota of lakes and reservoirs are more or less similar to those found in ponds. Reservoirs formed by the construction of dams across rivers will have riverine biota but will soon be succeeded by those adapted to still water situations.

According to Hubbs and Eschmeyer (1938), the major factors affecting the weed growth in lakes are: (1) latitude; (2) altitude; (3) topography of the bottom; (4) fluctuation in water level; (5) presence of harmful chemicals in the water; (6) turbidity; (7) productivity of water; (8) exposure to waves; (9) suitability of bottom materials; and (10) abundance of algae.

Excessive growth of weeds will be inimical to the normal life of the fish. Methods of weed control are similar to those applicable to ponds.

Lakes and reservoirs abound in extraneous and predaceous fish which form the major part of the fishery. The fish stocked in these waters must compete with the extraneous fish.

Selective poisoning by rotenone etc. may be conducted in these waters to remove the undesirable fish before stocking is initiated. Studies on the feeding and breeding grounds of these fish are necessary before any improvement work can be initiated.

2. Swamps

Swamps are extensive shallow water areas with excessive weed growth. They are formed in the bed of dead lakes. Some have the same characteristics as rice fields. Very shallow swamps can be converted into ponds and be managed as such, while deep water swamps can be reclaimed for management as lakes.

Swamp fishes are very hardy and usually belong to air-breathing species. Predaceous fish are also found in large numbers. Fishing is relatively easy in swamps because of their shallowness.

Reclamation of swamps in East Pakistan.--The Directorate of Fisheries, East Pakistan, has initiated a five-year project in 1957-1958 for the rehabilitation and development of 15,000 acres of fallow water areas in this province. For the sake of efficiency in operation, the entire area has

been divided into 90 units, each unit comprizing about 160 acres. Each unit is commercially self-sufficient and economically independent, therefore, success or failure of one will not vitally affect the other.

The expenditure incurred in the development work is expected to be recovered with profit from the proceeds of the sale of fish produced in these waters. Table 24 shows the swamps which were under development during 1957-58 (Ahmad, 1958).

3. Irrigation Canals

Irrigation canals carry water from rivers or reservoirs to agricultural lands. There is always a likelihood of marked variation in the water level in these canals. However, it may be found possible in suitable localities to partition off sections of a canal by means of bamboo through which water can flow freely but the fish cannot escape. Where this is not possible, an entire canal system can be managed as a single unit in which migratory fish can be cultured.

4. Stocking

Any cultivated fresh-water fish can be stocked depending on their availability, local demand, and profitability. Introduction of exotic fish like Tilapia spp., Puntius javanicus, Cyprinus carpio, and Osphronemus gourami may be considered here.

TABLE 24. Development of swamps for fish culture in East Pakistan, 1957-1958^a

Name of District		Area (acres)	Cost (rupees)	Estimated fish pro- duction (maunds)	Estimated income in 1962 (rupees)
Jessore	Bahular Baor	645	134,138	5,400	162,000
	Joydia Baor	535	89,669	4,000	120,000
	Habulla				
	Rustampur Baor	76	47,030	1,750	56,000
Dacca	Narayanganj	18	24,450	1,006	35,210
Bogra	Raktadaha Beel	500	83,076	6,600	99,000
	Narail Beel				
	and Sakharla Danga	150	43,492	2,700	48,200
Rangpur	Bamandanga Beel	70	25,036	1,065	36,000
Kushtia	Chand Beel	100	22,700	615	24,600
	Ganges-Kobadak Lake	33	15,318	875	26,250
	Chandona Doba	70	18,500	516	22,500
	Banderdah	180	36,544	850	38,000
Mymensingh	Shampur Mora Beel	230	41,235	1,665	49,957
	Baleswar-Kutiakuri Beels and Chowka Baor	100	17,844	850	25,500
	Diara Nadi	200	41,424	1,650	57,050
	Sarbamangal Doba, Betal & Khama Beels	170	26,822	1,400	42,000
Dinaipur	Dinaipur	12	1,500	90	3,150
Sylhet	Fategang Beel	170	22,680	3,000	36,000
	Anduganj Beel	270	36,284	4,200	50,400
	Kaibara Fishery	83	14,916	1,600	19,200
	Palui Beel	1,700	91,470	9,000	135,000
	Aralikona Beel	870	67,284	5,000	75,000
	Moraganj Fishery	100	15,966	1,200	21,600
Totals		6,282	917,378	55,032	1,182,617

1 rupee = U.S. \$0.21

1 maund = 82 pounds.

Net income . . Rs 265,239

^aSource: Ahmad (1958).

The rate of stocking of these waters has not been determined. Population estimation and survey of biota will have to be undertaken for this purpose. However, it will not be necessary to continue stocking after a few years as the fish should establish themselves by breeding there.

Other important measures that may help to improve the fisheries in such waters are the provision of shelters and fertilization. Very little work has so far been done in Pakistan on this aspect. The results of work done by Hubbs and Eschmeyer (1938) on the improvement of lakes in Michigan for fishing may be a good basis for experimental work.

5. Fishing and Marketing

Dragnets and castnets are not very efficient for fishing in these waters. Gillnets have, however, been found quite suitable.

If the fisheries are situated near a city or township, the catch can be sold fresh, otherwise they should be either chilled in ice and transported for sale to a distant market or a portion of them cured.

J. Fish Culture in Rice Fields

Probably China was the first to start fish culture in rice fields. However, the practice of regular fish culture in rice fields is reported to be on record in Indonesia for the past 100 years (Ahjar, 1955a; Ardiwinata, 1957).

Early in the present century, Nicholson (1917) advocated fish culture in the extensive rice fields of Madras, India. Instances of fish crops from rice fields have since recorded from many rice growing countries of both hemispheres.

Rice being the staple food of the Pakistanis, rice fields occupy a large share of the arable land. It is necessary to keep a certain depth of water in the fields for rice cultivation and since many of them are left fallow for varying periods of time after the crop is harvested, such fields offer conditions well-suited for fish culture. Schuster (1952b) estimates that fish culture is possible in 20 million acres of rice fields in East Pakistan. When fertilized and inundated for rice growing, rich biota develop in the water and through fish culture these can be utilized for the production of fish. Simultaneous production of grain and animal protein on the same piece of land is an ideal method of land usage (Schuster, 1955a).

Fish culture in rice fields is of great significance in the rural economy of East Pakistan, but little work has been done here by deliberately preparing the fields for stocking them with fish. Recently a project "rich-cum-fish culture" or raising fish with rice at the same time, has been submitted to the Government by the provincial Directorate of Fisheries for consideration (Ahmad, 1956b).

In East Pakistan, rice fields are flooded with rain water to a depth of 2-6 feet. Adjoining and connected to the

fields are several ponds; besides, there is a system of narrow canals intended for drainage of surplus water from the fields. During the rainy season, these canals serve as free passage for young fish to the fields. Fishes take shelter in the deeper ponds when the water recedes. Rice is harvested in December, and by January-February, wild fishes like Colisa, Ophicephalus, minnows, spiny eels, catfishes, climbing perch, and small shrimp are harvested by means of castnets, gillnets and bamboo traps. At present, the production of wild fishes in rice fields of East Pakistan is about 20 pounds per acre.

Fish culture in rice fields may be divided into: (1) fish culture as second crop; (2) fish culture between two rice crops; and (3) rice-cum-fish culture. The first form of fish culture is possible in fields where rice is grown once a year, the rest in those where two or more rice crops are grown annually. See further page 195.

1. Water and Soil Conditions

A suitable depth of water (at least 10 inches) and fertility of the soil as well as water are necessary for profitable fish culture. Rice fields in East Pakistan are usually wet but fish culture is most successful in those fields where controlled irrigation is possible.

Fertility of the soil has a great role to play in rice as well as fish production. The cultivator fertilizes the fields before sowing or planting rice. As the field is inundated by rain water, some nutrients dissolve in the water and

fish food grows rapidly.

2. Biota

The planktonic organisms in rice fields are similar to those found in shallow ponds and swamps. Mosquitoes find suitable conditions to breed here. Larvivorous fishes feed on the larvae of mosquitoes and other insects.

The wild fish fauna are generally predaceous and must be excluded if an extensive fish culture is planned. Field mice live in the embankment during the harvesting season and damage the embankments by boring through them. They also feed on rice in the field. This menace should be minimized by some suitable method like trapping or killing them with poison. Piscivorous birds may also be a menace to cultured fish. They should be scared away by some suitable devices or be shot.

3. Preparing the Field

Since a suitable depth of water must be maintained in the field, strong embankments (bundhs) around it will be necessary. For fields in which Tilapia is cultured, a height of about 60 cm. is recommended for the bundh to prevent the escape of the fish and the flooding of the field. Vegetables can be grown on wide bundhs. Necessary earth for the bundh will be available by digging a narrow canal around the inner margin of the existing bundh. This canal will serve as a refuge for the fish from solar heat as well as predators. When the water recedes from the field, they will gather in

this canal and harvesting will be facilitated. The depth and width of the canal will vary according to the fish cultured; for Tilapia, it may be 75 to 150 cm. (Hora and Pillay, 1962).

4. Stocking

Cultivated fish that can (1) thrive well in shallow waters; (2) withstand turbidity due to suspended clay; (3) tolerate relatively high temperatures and low oxygen tension; and (4) grow to marketable size in a few months are most suitable for stocking. Common carp (Puntius javanicus), Tilapia melanopleura, gourami, etc. can be grown in East Pakistan's rice fields (Schuster, 1952b). When an association of common carp, Puntia, and Tilapia is planned, 750-1,500 fingerlings per hectare may be stocked (Hora and Pillay, 1962).

Hora (1951b) reported that an experiment on rice-cum-fish culture was conducted in Bengal in May, 1945 and, for future reference, its results may be quoted here (Table 25.) From the figures it appears that the profit was as high as 440%. Of the fry stocked, 56,850 were planted in ponds adjoining rice fields, and, according to Hora, the growth of pond fishes was slower than those stocked in the fields. Some fish measured as long as 16 inches in rice fields while the largest fish recovered from the pond was only 11 inches. It was estimated that, taking into consideration the full annual production of the fish stocked in the ponds, the production figure in rice fields might have been as high as 246,000 pounds

TABLE 25. Results of experiment on rice-cum-fish culture in Bengal in 1945^a

Area of rice fields brought under the project	691.16 acres
Number of carp fry (<u>Catla</u> , rohu and mrigal) stocked	407,100
Size of fry stocked	0.75-2.5 inches
Cost of fry	Rs 4,502.60
Cost of fry transport	Rs 1,124.50
Total number of fish harvested	224,158
Range of size of fish recovered	5-12 inches
Total weight of fish recovered	64,452 pounds
Value at Rs 40 per maund	Rs 31,440

1 Rupee = U.S. \$0.21; 1 maund = 82 pounds.

^aSource: Hora (1951b).

(358 pounds per acre) at the end of one year.

In another rice field, where carps were stocked on the first of September, 1945 and harvested on the 15th of November, 1946, Hora (1951b) found the following rate of growth in them:

Species stocked	Size of fry (inch)	Average growth in length in ponds (inch)	Average growth in length in rice fields (inch)
<u>Catla</u>	1.7	6.0	7.8 (9.0 largest)
Rohu	1.5	5.0	6.2 (7.3 largest)
Mrigal	1.4	5.2	6.2 (7.0 largest)

He further found that the survival rate was 34% for Catla, 37% for rohu and 39% for mrigal. This shows that bottom-living mrigal was somewhat safer from predatory birds even in these shallow waters. Mrigal was found useful in the tilling of rice fields but the best results were obtained when all three species were stocked together.

5. Management

In fields where the depth of water is unsatisfactory, great care must be taken to protect the fish from predatory birds. Excessive growth of filamentous algae should be checked. Regular inspection of bundhs and the water level are also essential.

6. Economic Aspects

Advantages.--The advantageous effects of fish culture

on rice can be summarized as follows:

a. Fish as a second crop:

- 1) The cost of preparing the field for rice cultivation decreases by about 30% (Ardiwinata, 1957).
- 2) The cost of weeding is lower.
- 3) The yield of rice increases by about 7% (Grist, 1959).

b. Fish between two rice crops:

- 1) The field benefits from longer fertilizing action of the water.
- 2) Income derived from fish helps to meet the expenses necessary for preparing the field.
- 3) In case of irrigation, the soil becomes softer and yields better to the plough.

c. Rice-cum-fish culture:

- 1) Water supply is better controlled.
- 2) Aquatic weeds are better controlled.
- 3) Movement of fish aerates the soil.
- 4) Possibly organic substances are better mineralized.
- 5) Disease and pests (stem borer, for example) of rice are more efficiently controlled (Schuster, 1955b).
- 6) Yield of rice increases by about 15% (Hora, 1951b).

Disadvantages.--Among the disadvantages, the following

may be cited:

- 1) Cost of fish for stocking.
- 2) Expense of enhanced manuring.
- 3) Improvement of field embankments.
- 4) Digging ditches and pits which may reduce yield

of rice.

- 5) Cost of artificial food, if any.
- 6) Care from predation and disease.
- 7) Likelihood of rooting out of rice plant by the fish.
- 8) Keeping water level fairly constant.

In irrigated fields, additional water supply especially for fish culture may not always be possible. Besides, shallow water in the fields may warm excessively leading to unfavorable conditions.

The most opportune time for stocking will have to be determined by repeated and careful experimentation. Plankton production in the field is likely to be maximum soon after flooding. If the fish cannot be introduced at that time, it will become necessary to select such fish as could be advantageously introduced at a later stage.

Shallowness and seasonal character of water are peculiar features of this type of fish culture. Conditions are therefore likely to vary with locality. In view of these disadvantages, it becomes essential to:

- 1) Carry out a well-planned survey of the prevailing conditions in different districts of East Pakistan (Figure 7) especially with reference to depth of water, season and its duration, and availability of stocking material.
- 2) Launch a systematic project of field requirements

to elucidate the various problems requiring solution. Without this, large scale utilization of rice fields for fish culture may carry with it the risk of expectations being not fulfilled.

The use of inorganic fertilizers, especially ammonium sulfate in quantities needful for rice but harmful to the fish, and of calcium cyanamide which is toxic to fish, are adverse factors. Worst of all, however, are the new selective herbicides such as 2,4-D which is poisonous to fish, and the insecticides such as dieldrin and endrin which are fatal to fish even in extreme dilutions. Thus it may appear that fish culture is incompatible with modern agents for weed control as well as controlling insects injurious to rice (Tonolli, 1955; Grist, 1959; Hickling, 1962). But in view of the desirability of encouraging fish production as a means of improving the diet of the people, it would be a folly also to advocate the use of chemicals particularly in those fields where rice and fish are being raised together.

K. Fish Culture in Brackish-water Swamps and Rice Fields

The deltaic area of East Pakistan consists of numerous islands criss-crossed by a net-work of tidal streams of varying sizes and overgrown in many instances by dense forests. This region, known as the Sundarbans (Figure 7), abounds in low swampy lands which are completely inundated

during high tides and partially or fully exposed during low tides. By the rapid silting of creeks, tidal streams, and tributaries of rivers or by the changing of their courses, additional low marshy lands are constantly being formed there.

To increase food production and to release pressure on the cultivated lands in this province, reclamation of deltaic area has become necessary. It involves the raising of level of the land and removal of salt content from the soil to make it suitable for rice cultivation. Though the ultimate aim of reclamation is agricultural utilization, raising of fish is intended to be done only during the interim period of varying duration. However, in recent years, there is an increasing realization that, in some cases, it is possible and profitable to manage such areas purely as fish culture establishments by constructing and managing ponds. Since the work of reclamation will require large expenditures, it will necessarily be a slow process. Many fields after reclamation on the Indian side of the Sunderbans have been used for rice-cum-fish culture. Hora and Nair (1944), Pillay (1954, 1958), and Pillay and Bose (1957) have made valuable studies on fish cultural practices in these areas.

1. Reclamation of Saline Swamps

The first step in the reclamation of these swamps

will be the construction of a strong, high embankment around the area selected to stop flooding with tidal water. Necessary earth for the embankment will be obtained by digging a canal around the site. Its height should be about 30 cm. above the maximum flood level. On the side facing the source of water, a sluice gate is installed in the embankment to regulate the water supply. It is opened during high tide to let the water in, and closed at low tide to stop the water from draining.

The embanked swamp is locally called bheri. Some bheris are quite deep and unfit for rice cultivation and they may be compared with shallow lakes. Tidal water carries sufficient amount of silt and a good part of it settles in the bheri. This gradually raises the level of the swamp thus making it fit for rice transplantation; but the soil of such bheri is salty enough to make it an uneconomic proposition. To remove salt, the bheris will have to be flushed with rain water and the entrance of tidal water checked.

2. Fish Culture during Reclamation

Since reclamation of bheris takes 15 to 20 years to complete, the farmer makes some inexpensive arrangements for fish culture in them. These are, besides the main canal all around the embanked area, (1) digging a net-work of smaller canals across the selected swamp for easy drainage, and to give suitable shelter to the cultivated fish, (2) erection

of V- or W-shaped bamboo structures in front of the sluice gate to prevent the entrance of undesirable fish or other animals into the bheri. At the apex of the V- or apices of the W, traps are set to capture fish swimming against the current when tidal waters are taken in.

The bheri, where fish culture is practiced, is kept closed to tidal water and dewatered from September to January. After January, it is kept open till about September. During this period the following fishes and shrimps of economic importance along with many less important species enter the bheri: Fish--(1) Gray mullets (Mugil parsia, M. tade, and M. corsula); (2) Perch (Lates calcarifer); and (3) Nona tengra (Mustus gulio). Shrimp--(1) Common shrimps (Peneus semi-sulcatus; Metapeneus monoceros; and Leander styliferus).

Stocking--For selective stocking of the bheris, fry or gray mullets are collected from creeks, canals, borrow-pits and estuaries. High tide brings them into the creeks and borrow-pits. At low tide, the narrow creeks are bunded off and, in the case of borrow-pits, the fry are stranded and the fishermen collect them with a large rectangular piece of coarse cloth. The mullet fry are sorted out from those of other species and shrimps and transported in earthen jars like the carp fry. In South India, the mullet fry are conditioned before they are released into the stocking ponds some of which are fresh-water. The collection and acclimatization of mullet fry are not extensive in East Pakistan

but the fish culturist in the coastal districts should be encouraged to start the practice.

3. Ecology of a Typical Bheri

There is a marked fluctuation in salinity of water during the period of fish culture, ranging from less than 0.5% in August-November to 31.5% in May (Pillay and Bose, 1957). See also Pillay et al. (1962).

The profuse growth of algae such as Oscillatoria, Lyngbya, Anabaena, Spirogyra, Cladophora, Vaucheria, Euglena and diatoms like Nitzschia and Navicula form an important source of food of the cultivated fish. The only aquatic phanerogamic plants are Ruppia spp. which can withstand salinity up to 60 parts per thousand. The major zooplanktonic organisms include flagellates, copepods, rotifers and nauplii of crustaceans. Gray mullets and shrimps feed on algae. Lates calcarifer, being a carnivore, feeds on small fishes and shrimps. Mystus gulio is an omnivore and feeds on algae as well as small crustaceans.

Pillay (1954) conducted experiments on the chemical composition of soil of bheris. His results are shown in Table 26.

4. Capture

Fishing starts in October when water is no more taken into the bheri. It is done by means of seines and bamboo traps ("atols"). Mugil parsia attains a length of 10-15

TABLE 26. Chemical analysis of the soil of a typical Bheri^a

Chemical content of soil	%
Silica and other insoluble matters	79.47
Iron and aluminum as oxides	8.88
Calcium as CaO	3.34
Phosphate as P ₂ O ₅	1.53
Magnesium as MgO	1.12
Total nitrogen	0.42
Chlorides	0.137
Sulfates as SO ₃	0.05
Nitrate nitrogen	0.004
Other	<u>4.849</u>
Total	100.000

^aSource: Pillay (1954).

cm., M. tade, 22-25 cm., and Lates calcarifer, 12-25 cm. by the end of November; common shrimps (Peneus semisulcatus and Metapeneus monoceros) grow up to 13 and 10 cm. respectively. Catches are generally kept in small ponds near the main sluice gate for sale alive. Many farmers transfer small fish into separate rearing ponds and release them again into the bheri during the following January or February.

5. Fish Culture after Reclamation

Brackish-water swamps reclaimed for rice culture have the same embankment and canal system which are kept in good condition by the farmers. The harvesting of rice ends by about January, when the field as well as the canals is completely dry. During spring tides, the young fish enter the canals where they get favorable conditions for their growth because of the shallowness of water and the consequent rich growth of food.

With the start of the south-west monsoon in June, the water level goes up in the canals, and the sluice gates are closed against tidal water. The fields are manured with cow-dung and other organic fertilizers and rice is transplanted. As the monsoon is intensified, water level goes up in the canals and subsequently the fields are flooded and the fishes gain access to the plots. Excessive water is, of course, drained into the river through the sluice gate at low tides. The monsoon being over by November, the fields

begin to dry up and the fishes fall back into the canals and the fishing operations are started. They are caught either by seines or by letting some tidal water in when they swim against the current and are trapped in "atols" placed in the gaps of the bamboo fencing.

The stocking operation in rice fields are rather crude, but the analysis of sample catches from these fields indicates that only 2% of the weight of catch consists of uneconomic species. About 31% consists of Mugil parsia, 14% M. tade, 16% M. corsula and 33% Lates calcarifer; Mustus gulio represents 4% (Pillay and Bose, 1957). Among the shrimps, the more important species are: Palaemon carcinus, P. rudis, Peneus semisulcatus, Metapeneus monoceros and M. brevipes.

Lates calcarifer and the gray mullets show a remarkably high rate of growth in the brackish-water rice fields. On an average, during the period of culture (September to November), Lates showed 182% increase in length, while Mugil tade and M. parsia 117 and 81% respectively. Lates grows much faster in rice fields than in the bheris or estuaries. The yield of fish is about 150 pounds per acre of rice field without affecting the yield of rice (Pillay and Bose, 1957).

Research by Schuster (1952c) shows that Puntius javanicus and Tilapia can be reared in brackish-water ponds. He reports that Tilapia eats a certain amount of small shrimps so that it will be an error to stock it in a pond

from which a rich crop of shrimp is expected. The general principles of management of brackish-water ponds are similar to those for fresh-water ponds. As of now, fish culture in brackish-water swamps, rice fields, and ponds either during or after reclamation of land is not very intensive and there is much scope for improvement by way of selective stocking and general improvement of cultural practices.

6. Economic Considerations

As already mentioned, fish culture in brackish-waters is only a stage in the reclamation of waste lands for rice cultivation. While during the period of reclamation the farmer may not earn anything from the land itself, he may be able to get a substantial income by raising fish for himself and for sale. The construction of embankments, sluice gates, canals, traps, etc. are not very costly. Fry of mullets and shrimps are abundant in the area. The farmer does not wait for some income but begins to earn money shortly after the start of the farm by selling mangrove stems as fuel, their bark for tanning nets and hides, by selling skin of lizards and snakes and also by marketing extraneous species of fish caught from the area. Wherever possible, salt making can also be undertaken. In this way, an enterprising farmer can start a multipurpose farm in the deltaic area in a profitable way.

IV. CONCLUDING REMARKS

Although fish culture is practiced as a skilled art, considerable experience and traditional knowledge have gone into the evolution of the techniques. However, proper extension of the practices have been greatly hampered for lack of sufficient knowledge of the basic scientific principles. This has been keenly felt after the independence of Pakistan in 1947. Besides, rapid increase in population in recent years has made it imperative to tap every available resource of food production. To make the necessary technical guidance available, agencies like the Food and Agriculture Organization of the United Nations have been organizing training centers and other means of dissemination of scientific knowledge on the subject of fishery extension services. See further Schuster (1952d), Ahjar (1955b). If the present tempo of development in research and development expressed in the formation of Fishery Development Corporations in both East and West Pakistan continue, it can justifiably be hoped that the industry would advance very rapidly during the coming years.

Hickling (1961) observed that the greatest of the tropical inland fisheries or the fisheries of the floods,

will decline in the next 100 years. The human population is increasing too rapidly. The rivers will be trained between embankments and the lands will be settled for intensive cultivation. As the wild fisheries decline, the importance of fish culture is bound to increase.

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APPENDIX

A COMPREHENSIVE LIST OF FRESH-WATER FOOD FISHES OF PAKISTAN ARRANGED ACCORDING TO THEIR ECONOMIC IMPORTANCE

Family	Scientific name	Local name	
		East Pakistan	West Pakistan
Cyprinidae	<u>Catla catla</u> Hamilton	Katla	Theila
	<u>Labeo rohita</u> Hamilton	Rohu	Rohu
	<u>Labeo calbasu</u> Hamilton	Kalbaus	Dhai
	<u>Labeo nandina</u> Hamilton	Nandin	na
	<u>Labeo gonius</u> Hamilton	Ghani	Seereha
	<u>Labeo diplostomus</u> Haeckel	Kulki-bata	Gid
	<u>Labeo bata</u> Hamilton	Bata	na
	<u>Labeo angra</u> Hamilton	Kharsa	A
	<u>Labeo boga</u> Hamilton	Bagna	Bhangan
	<u>Labeo sindensis</u> Day	A	Gheri
	<u>Labeo dyochilus</u> McClelland	A	Butal
	<u>Labeo nigripinnis</u> Day	A	Kali
	<u>Labeo fimbriatus</u> Bloch	A	na
	<u>Cirrhina mrigala</u> Hamilton	Mrigal	Mrigal
	<u>Cirrhina reba</u> Hamilton	Reba	Sunni
	<u>Crossocheilus latia</u> Hamilton	Kala bata	Taler
	<u>Barbus tor</u> Hamilton	Mahal	Mahsir
	<u>Barbus sarana</u> Hamilton	Sarpunti	Kharni
	<u>Barbus sophore</u> Hamilton	Punti	na
	<u>Barbus stigma</u> Cuvier and Val.	Punti	na
	<u>Barbus chonchonius</u> Hamilton	Kanchan punti	na
	<u>Barbus ticto</u> Hamilton	Titapunti	na
	<u>Barbus phutunio</u> Hamilton	Phutuni- punti	na
	<u>Barbus puntio</u> Hamilton	Bhadipunti	na
	<u>Barbus chola</u> Hamilton	Kerrundi	A
	<u>Barbus hexastichus</u> McClelland	A	Lubar
	<u>Barbus chagunio</u> Hamilton	Jarua	na

Family	Scientific name	Local name	
		East Pakistan	West Pakistan
Cyprinidae (continued)	<u>Aspidoparia morar</u> Hamilton	A	Chilwa
	<u>Amblypharyngodon mola</u> Hamilton	Moa	A
	<u>Amblypharyngodon microlepis</u> Bleeker	na	na
	<u>Barilius vagra</u> Hamilton	Koksa	Lohari
	<u>Barilius bendelinsis</u> Hamilton	Joia	Chal
	<u>Barilius barila</u> Hamilton	Caedra	na
	<u>Barilius barna</u> Hamilton	Bhola	na
	<u>Barilius tileo</u> Hamilton	na	na
	<u>Rasbora elonga</u> Hamilton	Along	na
	<u>Rasbora daniconius</u> Hamilton	Bayi	na
	<u>Esomus danricus</u> Hamilton	Dadhikha	na
	<u>Rohtee cotio</u> Hamilton	Goonta	na
	<u>Laubuca laubuca</u> Hamilton	Dankena	na
	<u>Danio devario</u> Hamilton	Banspata	A
	<u>Danio equipinnatus</u> McClelland	Chebli	A
	<u>Danio dangila</u> Hamilton	Nipati	A
	<u>Danio rerio</u> Hamilton	Anju	A
	<u>Danio chrysops</u> Cuvier and Val.	na	na
	<u>Chela gora</u> Hamilton	Ghora- chela	Chal
	<u>Chela bacaila</u> Hamilton	Banspati	Parranda
	<u>Chela phulo</u> Hamilton	Chela	A
	<u>Garra gotyla</u> Gray	A	Kurka
	<u>Garra monti-salsi</u> Hora	A	na
	<u>Scaphiodon readingii</u> Hora	A	na

Family	Scientific name	Local name	
		East Pakistan	West Pakistan
Siluridae	<u>Wallago attu</u> Bloch and Schneider	Boal	Mulee
	<u>Silonia silondia</u> Hamilton	Bacha	na
	<u>Clarias batrachus</u> Linnaeus	Magur	A
	<u>Saccobranchus fossilis</u> Hamilton	Singhi	Singhi
	<u>Pangasius pangasius</u> Hamilton	Pangas	na
	<u>Pseudeutropis garua</u> Hamilton	A	Bachwa
	<u>Pseudeutropis murius</u> Hamilton	A	Pahari
	<u>Eutropiichthys vacha</u> Hamilton	Bacha	Jhalli
	<u>Callichrous bimaculatus</u> Bloch	Kani	Pallu
	<u>Callichrous pabda</u> Hamilton	Pabda	na
	<u>Glyptothorax pectinosternum</u> McClelland	A	Mochi
	<u>Ailia colia</u> Hamilton	Banspata	na
	<u>Clupisoma murius</u> Hamilton	Motusi	na
	<u>Clupisoma atherinoides</u> Bloch	Batasi	na
	<u>Clupisoma garua</u> Hamilton	Garua	na
	<u>Mystus aor</u> Hamilton	Air	na
	<u>Mystus gulio</u> Hamilton	Nona tengra	na
	<u>Mystus corsula</u> Hamilton	Golsa tengra	na
	<u>Mystus cavaus</u> Hamilton	Kabasi tengra	na
	<u>Mystus tengra</u> Hamilton	Bajri tengra	na
	<u>Mystus vittatus</u> Bloch	Tengra	na
	<u>Liocassis rama</u> Hamilton	na	na
	<u>Arius gagra</u> Hamilton	Gagra	na

Family	Scientific name	Local name	
		East Pakistan	West Pakistan
Siluridae (continued)	<u>Bagarius bagarius</u> Hamilton	Bag mach	na
	<u>Glyptosternum cavia</u> Hamilton	Kani tengra	na
	<u>Erethistes hara</u> Hamilton	Kula kanti	na
Clupeidae	<u>Hilsa ilisha</u> Hamilton	Hilsa	Hilsa
	<u>Gadusia chapra</u> Hamilton	Chapila	na
	<u>Corica soborna</u> Hamilton	Subarna karika	na
	<u>Raconda russeliana</u> Gray	Kura phasa	na
	<u>Engraulis telara</u> Hamilton	Teoach	na
Ophicephalidae	<u>Ophicephalus marulius</u> Hamilton	Gajar	Saul
	<u>Ophicephalus striatus</u> Bloch	Shol	Saul
	<u>Ophicephalus punctatus</u> Bloch	Taki	Daula
	<u>Ophicephalus barka</u> Hamilton	Tila shol	na
	<u>Ophicephalus gachua</u> Hamilton	Gachua	Dauli
Notopteridae	<u>Notopterus notopterus</u> Hamilton	Pholi	na
	<u>Notopterus chitala</u> Hamilton	Chital	Pari
Anabatidae	<u>Anabas testudineus</u> Bloch	Koi	na
Ambassidae	<u>Ambassis baculis</u> Hamilton	Phopa chanda	na
	<u>Ambassis ranga</u> Hamilton	Lal chanda	na
	<u>Ambassis nama</u> Hamilton	Chanda	na
Osphronemidae	<u>Colisa fasciata</u> Bloch and Schneider	Khalisa	na
	<u>Colisa chuna</u> Hamilton	Chuna Khalisa	na
	<u>Colisa lalius</u> Hamilton	Lak-khalisa	na
Nandidae	<u>Nandus nandus</u> Hamilton	Bheda	na
	<u>Badis badis</u> Hamilton	na	na

Family	Scientific name	Local name	
		East Pakistan	West Pakistan
Belonidae	<u>Xenentodon cancila</u> Hamilton	Kakia	na
Cichlidae	<u>Tilapia mossambica</u> Peters	Tilapia	Tilapia
Mastacembelidae	<u>Mastacembelus armatus</u> Lacepede	Baim	Bam
	<u>Mastacembelus aculeata</u> Bloch	Tara baim	na
	<u>Mastacembelus zebrinus</u> Blyth	Pankal	na
Mugilidae	<u>Mugil corsula</u> Linnaeus	Bata	na
	<u>Mugil tade</u> Forskål	Bhangan	na
	<u>Mugil parsia</u> Cuvier and Val.	Kachki	na
	<u>Mugil cephalus</u> Linnaeus	na	na
Latidae	<u>Lates calcarifer</u> Bloch	Koral	na

Sources: Day (1873, 1958); Khan (1934); Ahmad (1953); Qureshi (1951); and FAO (1961a).

Explanation of notations:

A = not known to inhabit this province.

na = local name not known.

PLATES

PLATE I

Fresh-water food fishes of Pakistan

(Top to bottom)

- a. Catla catla Hamilton
- b. Labeo calbasu Hamilton
- c. Cirrhina mrigala Hamilton
- d. Barbus tor Hamilton

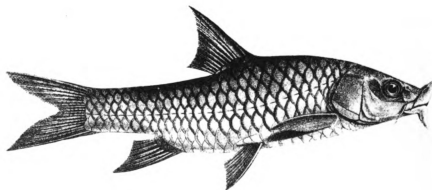
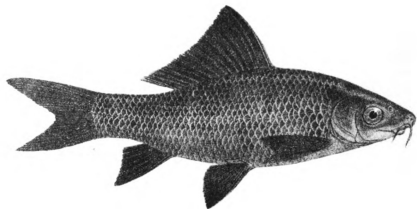
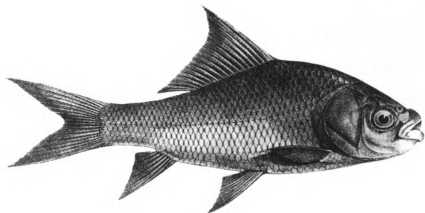


PLATE II

Fresh-water food fishes of Pakistan (continued)

(Top to bottom)

- a. Labeo nandina Hamilton
- b. Labeo gonius Hamilton
- c. Labeo rohita Hamilton
- d. Lates calcarifer Bloch (also found in
brackish-water)

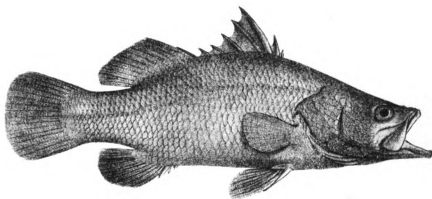
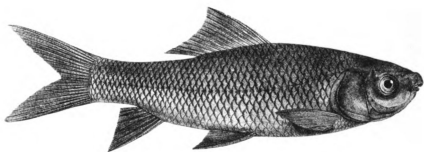
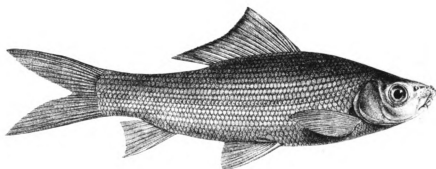
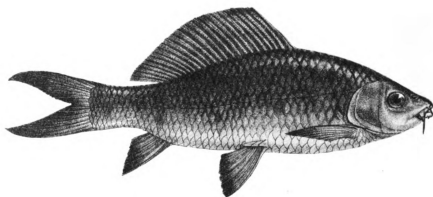


PLATE III

Fresh-water food fishes of Pakistan (continued)

(Top to bottom)

- a. Ophicephalus marulius Hamilton
 - b. Ophicephalus punctatus Bloch
 - c. Anabas testudineus Bloch
 - d. Wallago attu Bloch and Schneider
 - e. Saccobranchus fossilis Hamilton
- .

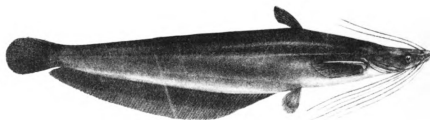
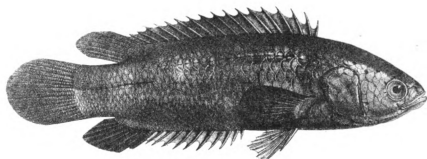
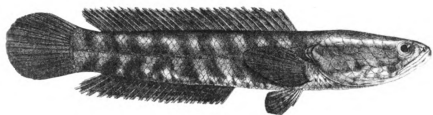
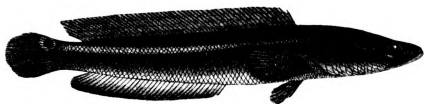


PLATE IV

Fresh-water food fishes of Pakistan (continued)

(Top to bottom)

- a. Colisa fasciata Bloch and Schneider
- b. Ambassis baculis Hamilton
- c. Notopterus notopterus Hamilton
- d. Notopterus chitala Hamilton

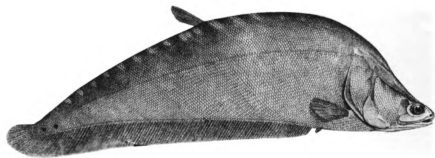
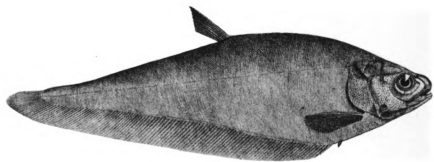
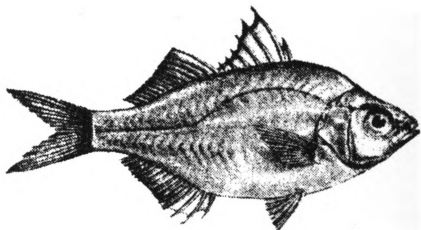
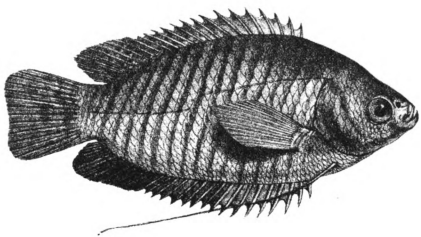


PLATE V

Fresh-water food fishes of Pakistan (continued)

(Top to bottom)

- a. Clarias batrachus Linnaeus
- b. Clarias batrachus Linnaeus with
labyrinthiform accessory respiratory
organs exposed
- c. Tilapia mossambica Peters (male)
- d. Tilapia mossambica Peters (female)

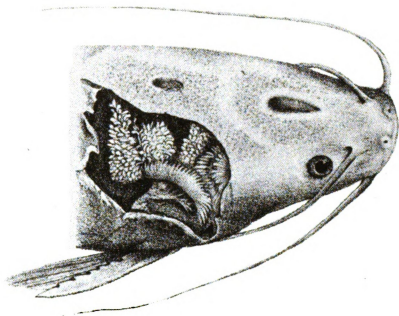
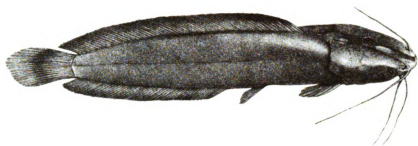
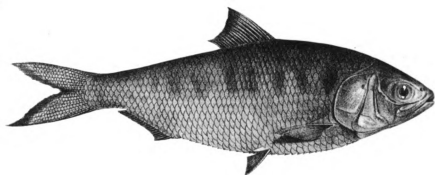
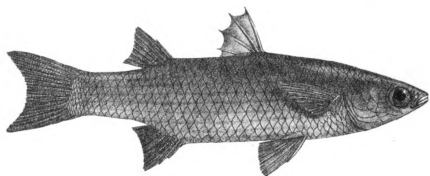
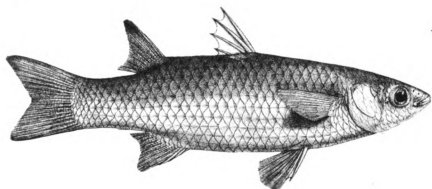


PLATE VI

Fresh to brackish-water food fishes of Pakistan

(Top to bottom)

- a. Mugil corsula Linnaeus
- b. Mugil parsia Cuv. et Val.
- c. Hilsa ilisha Hamilton



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